PROJECT REPORT

U.S.-China Air Quality Management Assessment Project

项目报告

中国美国空气质量管理评估项目

November 1999 – December 2003

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U.S.-CHINA AIR QUALITY MANAGEMENT ASSESSMENT

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EXECUTIVE SUMMARY

Introduction

In April 1999, Xie Zhenhua the Minister of the Chinese State Environmental Protection Administration (SEPA), and Carol M. Browner, the Administrator of the United States Environmental Protection Agency (U.S. EPA) at that time, signed a series of Statements of Intent outlining environmental issues for which the two countries intended to carry out cooperative programs. These Statements of Intent were developed in response to a Vice Presidential Initiative between the two countries on environmental cooperation.

One of the 12 Statements of Intent signed at that time outlined a program for assessing the Chinese air quality management process. This Statement of Intent (SOI) recognizes that air pollution is an important public health issue for both countries, and that current trends are likely to result in increasing human exposures to potentially harmful levels of air pollutants, especially in large cities. It also recognized that various approaches exist in China and in the U.S., for understanding and reducing air pollution in urban areas, and that air pollution experts from both China and the U.S. could benefit significantly from discussion and mutual exchange of techniques and approaches for addressing air pollution problems. In response to this SOI, U.S. EPA and SEPA initiated the joint U.S.-China Air Quality Management Assessment Project in October 1999. The objective of the project was to conduct a comparative assessment of the air quality management processes in China and the U.S and identify potential approaches that could prove effective in reducing air pollution. This assessment was intended to identify specific elements of the U.S. approach to air quality management that might strengthen the air quality management process in China, if these elements were transferred to and adopted in China.

The U.S.-China Air Quality Management Assessment Project focused in particular on air quality management in large urban areas. Shanghai, China's largest city, was chosen as a case study city to examine the air quality management processes at the municipal level in China. New York City was chosen as a case study city for comparative analysis of state- and municipal-level air quality management processes in the U.S. Additional innovative strategies that are being applied in Los Angeles, California are discussed as an example of how one local area can serve as a leader in air quality management, by experimenting with innovative programs to achieve significant air quality benefits.

The Air Quality Management Assessment team consisted of air quality management experts and environmental planning and policy experts from U.S. EPA, SEPA, the Chinese Research Academy of Environmental Sciences (CRAES), the Shanghai Environmental Protection Bureau (SEPB), the Shanghai Academy of Environmental Sciences (SAES), and the Shanghai Monitoring Center. This team receives technical support from a number of organizations and individuals in the U.S. and China, including in particular the U.S. and Beijing staff of the consulting firm ICF Consulting.

A number of information-gathering and cooperative assessment activities have been carried out during the course of the project, including missions by the U.S. team members to Beijing in November 1999, April 2000, and February 2001, and to Shanghai in May 2001. These missions entailed extensive information exchanges and discussion, as well as visits to key agencies, air quality monitoring facilities, air emission sources, and other sites and facilities in Beijing and Shanghai. During the April 2000 mission the U.S.-China team jointly hosted and participated in the International Workshop on Air Quality Management in Beijing, featuring presentations by top air quality management experts from China and around the world. Additionally, Chinese team members made a trip to the U.S. in March of 2002 for trainings is monitoring, modeling, and emissions inventories in Research Triangle Park, North Carolina and Washington, D.C.

This Assessment Report presents the findings and recommendations of the team. A comparison of the air quality issues and management approaches in the two countries at the national and municipal levels is presented, followed by an assessment of similarities and differences in these approaches. Section IV presents a summary of the team's conclusions, followed by a series of recommendations by the U.S. team for strengthening air quality management in China.

Air Quality Issues and Trends

Trend statistics for air emissions and for ambient air quality indicate that very significant strides have been made in both countries in controlling air quality over the past decade. In the U.S., national average ambient concentrations of all key air pollutants except ozone have declined significantly since 1990. Ozone concentrations have held steady over the period. Total emissions of volatile organic compounds (VOCs) and sulfur dioxide (SO_2) have declined significantly since their peaks in the mid-1970s, and total emissions of nitrogen oxides (NO_x) have declined slightly over the same period. Total emissions of small particulate matter (PM_{10}) have decreased steadily since the 1950s.

In China, a downward trend in urban air concentrations of SO_2, NO_x and total suspended particles (TSP) has begun in only the past several years, as a result of control measures instituted under China's Ninth five-Year Plan (1996 - 2000). China largely achieved its goal for this period of bringing major industrial emissions into compliance with emission standards, and in many cities achieved the goal of bringing ambient air quality into attainment of ambient standards. These reductions in air pollutant levels and increasing compliance with emissions standards represent a remarkable achievement that was accomplished during a period of rapid economic growth.

Significant air quality issues still remain in both countries. In the U.S., nonattainment areas are still developing plans for achieving attainment with ambient air quality standards. Measures for controlling very fine particulates ($PM_{2.5}$) are also still under development. China, including Shanghai, has set the goal of bringing all of its urban areas into compliance with its Level II ambient air quality standards (roughly on a par with World Health Organization health-based standards) for SO_2, NO_x and PM_{10}. Control programs for ozone, VOCs, $PM_{2.5}$, and air toxics are under development.

Air Quality Management Practices

The U.S. air quality management system is based on a series of key elements: goal setting; emissions inventory; air quality monitoring; air quality modeling; controls identification and policy development; implementation; and evaluation of effectiveness and adjustment of controls. Comprehensive technical capability and sophisticated analytical processes have been developed to support each of these elements. China's national government, and the Shanghai municipal government in particular, has significant capability in each of these management elements, and carries out each to varying degrees. Key comparisons and contrasts between the air quality management systems in the two countries (again, focusing on Shanghai as the case study in China) identified during this study include:

- Goal setting: The U.S. sets air quality goals based on the levels considered protective of human health and the environment. Air quality goals in China are generally established on a five-year planning cycle, and tend to be based on economic and technical attainability within the planning period;

- Emission Inventories: U.S. inventories are comprehensive, covering large industrial ("stationary") sources, smaller sources and area sources (treated collectively as "area" sources), mobile sources, and natural sources. Source inventories in Shanghai and other parts of China are reasonably comprehensive for large and medium-sized point sources. Inventories for area sources and mobile sources are under development;
- Air Quality Monitoring: The U.S. has a comprehensive nationwide monitoring network covering a wide range of pollutants including both primary and secondary pollutants. Consistent monitoring techniques, and data handling practices are employed at all monitoring stations in the national network. China's monitoring system is more limited in spatial coverage, and focuses primarily on three pollutants (SO_2, NO_x, and TSP). The sophistication of monitoring techniques varies from manual methods to automated real-time methods which complicates comparison studies between stations and the assessment of trends over time. Shanghai has begun an initiative to expand and upgrade its monitoring network, in order to place monitoring stations in many areas of the city that have developed into urban centers in recent years, and to increase the number of parameters monitored;
- Air Quality Modeling: The U.S. has sophisticated modeling capabilities, with modeling integral to the air quality management process. Models capable of simulating atmospheric chemical and physical reactions, and regional atmospheric transport and the fate of pollutants, are applied to project the effectiveness of proposed control measures; they help tailor control measures to the conditions and needs of each local area. Modeling capability and application in China and Shanghai is more limited. Models in use are generally Gaussian physical transport models, and modeling is not widely used as a basis for development of air quality control strategies;
- Controls identification: In the U.S., air quality control strategies for urban areas are developed at the state level by selecting from an eclectic "tool box" of control measures, including technological controls, operational and product content measures, and economic incentives. The specific mix of controls for a given area is selected based on modeling and assessment of the most efficient control strategy. In China, control measures are established both at the national level (nationwide emission standards) and at the local municipal level for large urban areas. Municipalities such as Shanghai have developed control strategies based on national guidelines, and on a largely intuitive assessment of the most important source categories to be controlled;
- Implementation: The two countries differ in their approaches to air quality control implementation. In the U.S., implementation is carried out by both the national and state levels of government. In China, implementation in large urban areas is almost entirely the responsibility of the municipal government. Source surveillance is relatively comprehensive and rigorous in the U.S., while it is less so in China due to limited capacity of enforcement agencies; and
- Evaluation and Adjustment of Control Measures: This is considered a key element of air quality management in the U.S. Evaluation is carried out almost constantly, and state-level control strategies are considered "works in progress," subject to frequent adjustment and updating as necessary. In China, control measures tend to be evaluated in line with the 5-year planning cycle, and new control strategies are often developed as part of the 5-year planning process.

Conclusions

The final section of this report summarizes the findings and conclusions of the U.S. component of the study team regarding comparative urban air quality management practices in the two countries, and summarizes the recommendations by the U.S. component of the team for strengthening air quality management in China's urban areas.

Throughout the course of this project, the U.S. component of the study team has been very impressed with the capability and dedication of the air quality management professionals in China who have participated in the project. The U.S. team has learned a great deal about the air quality management process in China, and about the progress made by China's air quality professionals in managing air quality in China's urban areas. Certainly, great strides have been made in improving air quality. In many of China's urban areas, including Shanghai, ambient air pollutant concentrations are trending downward even in the face of rapid economic development and a rapid increase in economic activity. This is indeed an impressive accomplishment.

China and Shanghai have solid, basic capabilities in each of the "building block" areas required for effective air quality management (goal-setting, emissions inventory, monitoring, modeling, control strategy development, implementation, and evaluation). Using these, Shanghai has identified and instituted control measures for key emission sources that were clearly major contributors to the city's air pollution problems. The control measures taken so far have been effective, and each has helped to move the city's air quality from a severely polluted state to compliance or near compliance with China's ambient air quality standards for three primary pollutants.

Although the participating Chinese air quality professionals have demonstrated a strong commitment to advancing air quality management programs, it is also recognized that pressing air quality issues remain to be addressed in China and Shanghai. Shanghai (as with Beijing and other urban areas in China) is poised to begin a new phase in air quality management. Shanghai has addressed many of the most apparent pollutant sources, but still needs additional reductions in air emissions in order to reach ambient pollutant levels protective of human health. Shanghai has reached a point where far more thorough and detailed assessment and analysis will be required in order to identify the most technologically effective and cost-efficient control strategies for going forward. Each incremental improvement in air quality from this point will become progressively more challenging and expensive.

To meet the challenge of continued improvement in air quality in Shanghai, the municipal government will need to develop more sophisticated capability in each of the basic air quality management building blocks. But perhaps most importantly, these strengthened building blocks will have to be linked together into a comprehensive air quality management *process* that is continual and iterative, and will support identification of the most effective and efficient air quality management strategies, policies, and programs for Shanghai in the future. The recommendations of the U.S. team are therefore focused in two areas: (1) shorter-term measures to strengthen the building blocks of effective air quality management; and (2) longer-term measures to strengthen the overall process for air quality management.

Recommendations

The U.S. team recommends that Shanghai should immediately begin to strengthen capabilities in four of the component building block areas – goal setting; emissions inventory; air quality monitoring, and air quality modeling. Specific recommendations are presented in the final section of this report and are summarized below:

- Goal setting: Base air quality goals on protection of human health and the environment. Establish a uniform health-based goal for all municipal areas and expand goals to cover additional key pollutants including fine particulate matter;
- Emissions inventory: Work to expand the emissions inventory to cover area and mobile sources and additional pollutants, particularly precursors for ozone and fine particulate matter. Enhance the capacity to study regional and local transport of pollutants, and chemistry of air pollutants. Initiate a short-term modeling effort for the assessment of sources of precursors for secondary pollutants in Shanghai using modeling tools provided by U.S. EPA (e.g., OZIP/EKMA). Develop source profiles for use in source apportionment. Implement a continuous improvement process to facilitate the development of more refined inventory data while other air quality management skills that depend on emissions inventories are developed. Establish approaches to define the location and timing of pollution sources, and develop capabilities to project emissions inventories to represent future year conditions;
- Air Quality Monitoring: Expand and upgrade the Shanghai monitoring network to increase both spatial and parametric coverage, and develop a filter analysis capability to assist in source identification/apportionment. Develop standard methods and analysis protocols to facilitate comparison studies and trends analysis; and
- Air Quality Modeling: Consider the wide range of modeling tools now available in the U.S. and carefully select and adapt modeling tools to fit Shanghai's current conditions, needs, and data availability. Establish training programs to develop the expertise and skills required to apply modeling tools to complex analyses. As expertise and data availability permits, move towards application of reactive, regional-scale models. Initiate a regional assessment to evaluate the regional transport of air pollutants in the region affecting Shanghai. Adapt and apply receptor modeling and source apportionment tools as a means of identifying the most important sources of ambient air pollutants.

Several recommendations are also offered for longer-term action in Shanghai. These include:

- Coordinate the inventory, monitoring and modeling efforts so that the building blocks are unified into an ongoing, iterative analytical process;
- Expand air quality control strategies to include additional pollutants, and develop a range or "toolbox" of control strategies that can be applied selectively to meet the specific needs of each locality;
- Consider a system to track compliance with emission limits, as well as inspection and enforcement tools, such as those included in U.S. EPA Method 9 in the U.S.; and
- Increase emphasis on controls evaluation, moving towards more frequent or constant evaluation and adjustment of controls to ensure attainment of air quality goals.

The following recommendations are offered for air quality management at the national level in China:

- Encourage the strengthening of air quality management, as recommended above for Shanghai, in urban areas nationwide, including the development of a national training center in Shanghai to transfer the skills and experience in Shanghai to other parts of China;

- Periodically revisit national-level air quality and emission standards; consider unified (single level) ambient air quality standards based on the protection of human health and the environment; assess and expand as appropriate pollutant coverage; evaluate emission standards in light of current technological advances in pollution control and cleaner production; and
- Consider the development of national technology standards, as additional “tools” in the toolbox of controls available to municipal governments in developing local air quality standards.

SECTION I. AIR QUALITY MANAGEMENT IN CHINA

A. NATIONAL LEVEL OVERVIEW

1. Issues and Trends

China has seen tremendous industrialization since economic reform began in 1978. Since then, China has relaxed and decentralized economic controls to permit the development of a more market-and incentive-driven economy. While this has led to increases in industrial output by more than 15 percent annually, it has also led to significant increases in air pollution.

If industry in China is to continue to grow at this rate over the next 20 years, a steep decline in pollution intensity will be necessary to keep emissions constant (Dasgupta et al., 1997). The effect of current atmospheric emissions levels in polluted cities is best displayed in the form of public health statistics. According to the World Resource Institute, respiratory disease is the number one cause of death in China. The World Bank has estimated, based on dose response functions and Chinese air quality data, that 178,000 premature deaths per year could be avoided by bringing Chinese urban areas into compliance with China's Class II residential air quality standards. This and other estimated health effects are shown in Table I-1 below.

Table I-1. Estimated Number of Respiratory Cases That Could Be Avoided per Year by Meeting Class II Air Quality Standards in China

Premature deaths	178,000
Respiratory hospital admissions	346,000
Emergency room visits	6,779,000
Lower respiratory infections or child asthma	661,000
Asthma attacks	75,107,000
Chronic bronchitis	1,762,000
Respiratory symptoms	5,270,175,000
Restricted activity days (years)	4,537,000

Source: The World Bank, *Clear Water, Blue Skies: China's Environment in the New Century*, p. 19.

Industrial and residential coal burning and vehicle emissions are the primary causes of air pollution in China. These sources emit a number of pollutants of concern, particularly sulfur dioxide (SO_2), particulate matter, and nitrogen oxides. China's State Environmental Protection Administration (SEPA) estimates that industrial pollution accounts for over 70 percent of the total national emissions of these pollutants. Coal fired electric power plants generate 80 percent of the country's energy and produce approximately 60 percent of all SO_2 emissions, making the country the world leader in sulfur emissions. In addition, China's consumption of raw coal has continued to increase over most of the last decade. From 1989 to 1993, SO_2 emissions increased by more than 20 percent and the concentration of total suspended particles (TSP) increased by approximately 10 percent. Much of this increase can be directly attributed to increases in coal consumption (WRI, 1999).

According to the World Health Organization (WHO), China is also home to eight of the ten cities with the worst air quality on the planet (Bridgenews Global Markets, 2000). More than 50 percent of the 88 cities tested for SO_2 and 97 percent of the 87 cities monitored for TSP in China exceed the WHO's guidelines (WRI, 1999). The U.S. Embassy in Beijing predicts that by the year 2010 annual SO_2 emissions will exceed 19 million tons (East Asian Executive Reports, 2001).

In addition to the various direct effects of air pollution, SO_2 emissions and vehicle exhaust also lead to the production of acid rain. Acid rain falls on more than 20 percent of the total national area. In some parts of China, the rainfall is ten times more acidic than unpolluted rain (UNEP, 1999). With these issues in mind, the Chinese government has identified air pollution as the chief environmental concern in China (Dasgupta et al., 1997).

Transportation

In addition to growing industrial production, the transportation system in China has significantly contributed to the degradation of air quality. The rapid evolution of Chinese urban areas has spawned a transportation system that is primarily based on petroleum-powered motor vehicles, producing emissions of carbon monoxide (CO) and nitrogen oxides that are rapidly approaching the magnitude/amount of emissions produced from the combustion of coal. In several Chinese cities (Beijing, Shanghai, Hangzhou, and Guangzhou), up to 70 percent of CO emissions have been attributed to the growing fleet of motor vehicles. In Beijing, the number of vehicles has increased at an average annual rate of 15 percent (East Asian Executive Reports, 2001; WRI, 2001; and WRI 1999).

Per capita, vehicle numbers are not excessive relative to other industrialized countries. In fact, the number of motor vehicles registrations is approximately three percent of those in the United States. However, increased vehicle use in a developing country such as China leads to 1.2 to 1.3 times more fuel consumption and 10 to 20 times more overall discharge than increased vehicle use in a developed country due to:

- Outdated technological practices;
- Poor manufacturing techniques; and
- Poor traffic management, maintenance, and infrastructure (WRI, 2001; WRI, 1999).

For these reasons, transportation issues are a primary cause of growing air quality concerns in China.

Financial Concerns

According to the World Bank, pollution costs China the equivalent of 8 percent of the gross domestic product (GDP) annually (Baldinger, 2000). It has been estimated that reducing pollution levels to China's Class II annual residential standard (average annual concentration of $SO_2 \leq 60\ \mu g/m^3$, $NO_2 \leq 80\ \mu g/m^3$, and respirable particulates $\leq 100\ \mu g/m^3$) could be a financially difficult task for the government. (See Section 1.2.1, National Air Quality Data, for a complete explanation of Class I, II, and III standards.)

In meetings with U.S. EPA experts in April 2000, Qu Geping, Chairman of the Ninth National People's Congress (NPC) Environmental Protection & Resources Conservation Committee, discussed the financial difficulty of improving China's air quality. During these meetings, he stated that improving air quality to China's Class II standard is not fiscally feasible. He estimated that reducing SO_2 and acid rain in control zones could cost the government RMB 180 billion (U.S. $21.8 billion), approximately 0.03 percent of the GDP within these zones. In Beijing alone, it has been estimated that investments of RMB 35 billion (U.S. 4.2 billion) up to as much as RMB 78 billion (U.S. $9.5 billion) will be necessary to reach these goals. He also noted that improving the air quality in 46 urban areas currently designated “key cities” will cost each city approximately 1.5 percent of their GDP, or U.S. $40 billion. It is possible that China will eventually add more cities to the key list (Edie News, 2000; East Asian Executive Reports 1999). Embassy sources have stated that Beijing would spend RMB 78 billion to clean up its air between 1999 and 2003. This figure includes municipal expenditures as well as central government inputs (Edie News, 2000).

Beijing, as seat of the national government and location for the 2008 Olympics, is clearly a special case in terms of available funding. Funding for pollution control in other Chinese cities is much less generous. A 1997 World Bank report entitled China 2020, estimated China would have to spend 2.1 percent of its GDP annually just to reach U.S. air quality standards of the early 1980s by 2020. Costs to achieve China’s Class II standards would be higher, since China's Class II standards are stricter than those enforced in the United States. China's GDP in 1999 was RMB 8.2 trillion (U.S. $1 trillion); 2.1 percent of this amount would equate to U.S. $21 billion. Qu Geping’s U.S. $40 billion estimate may therefore be overly conservative. However, the same World Bank report estimated that air pollution costs the Chinese economy U.S. $25 billion a year in health expenditures and lost labor productivity alone. In light of this, even U.S. $40 billion is not an unreasonable investment. Qu Geping and others who are concerned about air quality in China face the challenge of making a case for funding pollution control to a political leadership that confronts numerous other urgent, deserving, and under-funded priorities (Edie News, 2000).

a. National Air Quality Data

This section describes air quality in China in terms of commonly analyzed pollutants. Several major cities and their corresponding data are included to illustrate the contribution of industrialized areas to air quality on a national level. The extent and type of air pollution significantly varies by geographic region. See Figure I-1 for locations of cities mentioned in this section. Figure I-2 presents world cities that recorded high concentrations of total suspended particulates (TSP) and SO_2 by annual mean concentration in 1995 (WRI, 1999). Six out of these ten cities are in China. Note that the WHO guidelines are 60–90 $\mu g/m^3$ for TSP and 40-60 $\mu g/m^3$ for SO_2.

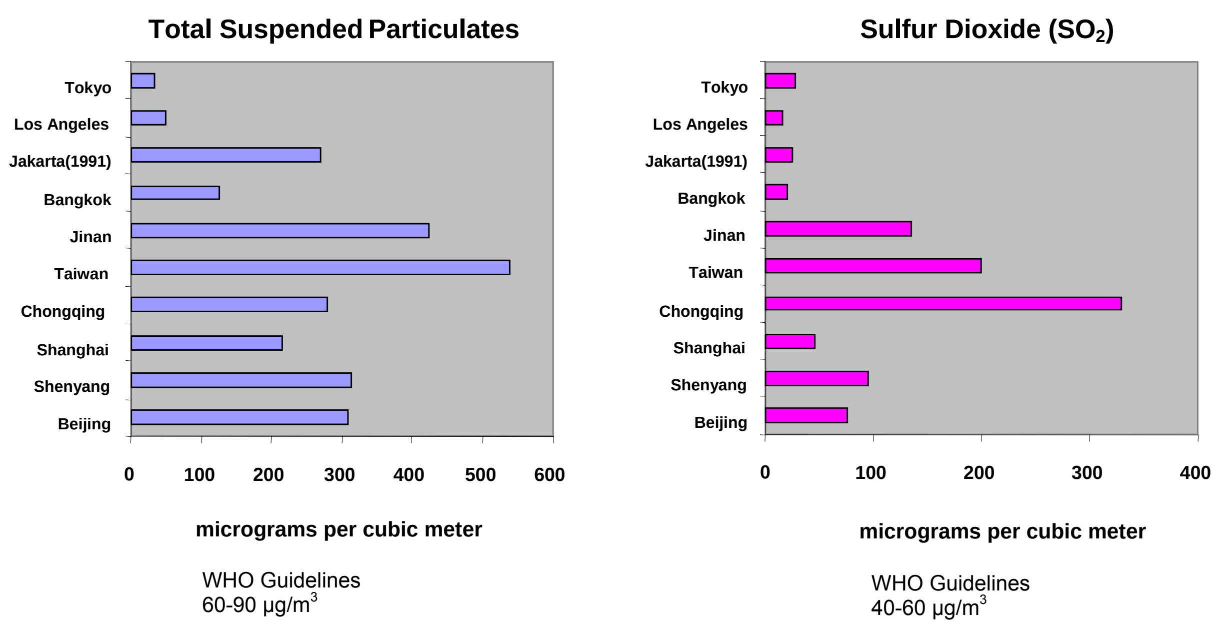
China’s National Ambient Air Quality Standards are divided into three classes as follows:

- Class I – “Park” or pristine zone standard,
- Class II – Residential zone standard, and
- Class III – Industrial zone standard.

The Class I standards for pollutants are the strictest, while the Class III standards allow the highest levels of pollutants and are therefore most lenient. WHO has also issued standards on some of the same pollutants including SO_2, TSP, fine particulate matter (PM_{10}), CO and nitrogen dioxide (NO_2).

Figure I-1. Map of China

Figure I-2. PM and SO_2 Concentrations Around the World



In China, particulate matter is primarily measured as TSP (rather than PM_{10} and $PM_{2.5}$ measurements that are now monitored in the United States and other countries). Research in both China and other countries has shown that PM_{10} comprises between 60 to 80 percent of TSP. Similarly, the World Bank assumes that PM_{10} comprises 60 percent TSP. According to the 1997 Environmental Situation Report (SEPA, 1997), 67 percent of the cities sampled exceed the TSP Class II residential standard of 200 $\mu g/m^3$. The national average TSP concentration during 1997 was 291 $\mu g/m^3$, with northern cities averaging 381 $\mu g/m^3$ and southern cities averaging 200 $\mu g/m^3$. Generally, the regions with the worst TSP pollution are urban areas, although dust blown in from the deserts also contributes to the TSP concentrations. Although routine monitoring for $PM_{2.5}$ has not been carried out, the limited measurements taken to date suggest that $PM_{2.5}$ levels may be of concern in China's urban areas.

Ambient SO_2 standards are also divided into three classes. In 1997, the national average SO_2 level was 45 $\mu g/m^3$, which is above the Class I annual standard. Over 30 cities also reported annual SO_2 levels above the Class II residential standard of 60 $\mu g/m^3$. The most heavily polluted cites were those in the southwest with high sulfur coal burning levels and those with high energy consumption in the north.

Nitrogen oxide (NO_x) pollution, another major air quality concern, is one of the three kinds of pollution centrally reported in China. NO_2, a major component of NO_x, is more frequently reported in the United States and other countries. Vehicle exhaust is the major cause of NO_x pollution in most cities. The national urban average NO_x concentration was 45 $\mu g/m^3$, which is equivalent to the Class I annual standard for NO_x. Beijing, Guangzhou, and Shanghai were the worst cites with annual averages of more than 100 $\mu g/m^3$ in 1997 (SEPA, 1997).

As is the case with $PM_{2.5}$, routine monitoring has not been widely carried out for ozone in China's cities. However, the limited measurements taken to date suggest that ozone levels may be of concern.

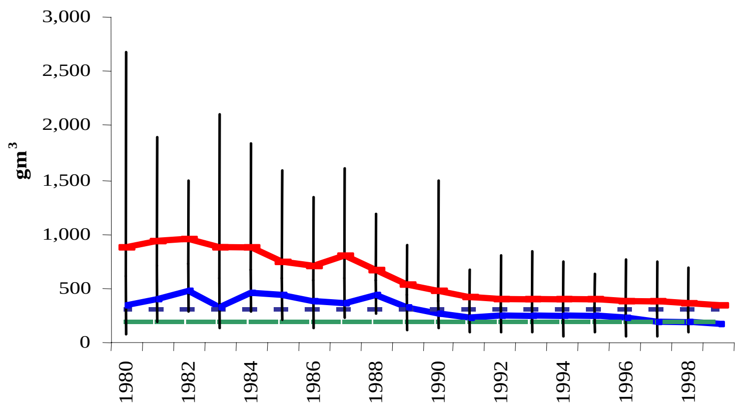
In the late 1990s, many of China's major cities began publishing ambient air quality data in newspapers on a weekly basis. The Shanghai Environmental Protection Bureau now publishes air quality data on its website. Dalian and Shanghai became the first cites to issue daily air quality reports in place of the more traditional weekly reports. The State Council has ordered more cities to make the transition to daily reporting.

In the northern cities, SO_2 and particulate emissions are the highest due to industrial dependence and cold temperatures for several months of the year that necessitates increased coal consumption. However, the coal consumed in the northern part of China is of higher quality (i.e., less sulfur content) than that consumed in the southern provinces such as Sichuan, Guizhou, Guangxi, and Hunan (WRI, 1999). While air quality remains a serious issue for these and many other cities in China, recent tapering off of increases as well as actual decreases in air pollutant concentrations point to the possibility of controlling and improving air quality conditions on a national level.

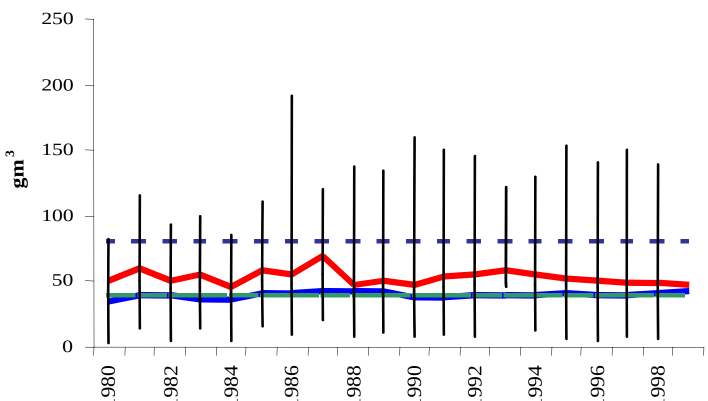
Figure I-3, showing annual average TSP, NO_x, and SO_2 concentrations for the period 1980-99, illustrates the effect of these differences in regional emissions on air quality. For TSP and SO_2, concentrations in the North have been consistently higher than in the South (although the gap is narrower than in earlier years). For SO_2, however, the difference is neither as pronounced nor as consistent. It is interesting to note that the annual average concentrations have trended

Figure I-3. Annual Average TSP, NO_x, and SO_2 Concentrations for the Period 1980-99

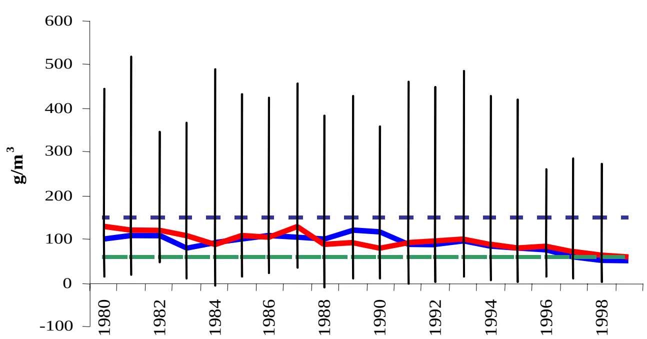
TSP



NO_x



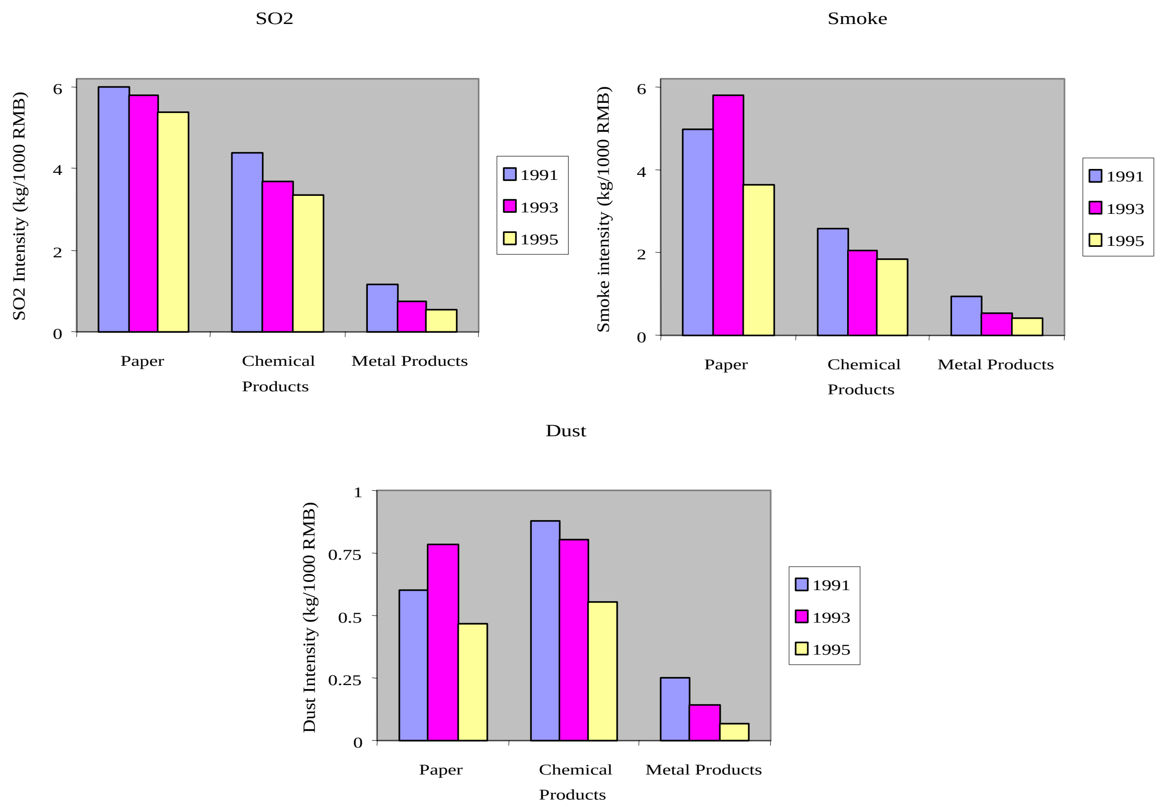
SO_2



Average of Southern Cities
Average of Northern Cities
Annual Average Standard
24-hour Average Standard Average

Vertical bars indicate ranges of values for all cities; the highest horizontal mark shows the most polluted of the Chinese cities.

Figure I-4. National Air Pollutant Intensities



downward since 1980, although the vertical bars show that a large gap between more and less polluted cities still exists, and has in some cases increased.

b. National Emission Data

From 1991 to 1995, the national air pollution intensity in China had shown a decreasing trend. However, this trend may be related to the change in calculation methods. Figure 1.4 shows changes in the air pollution intensity for SO_2, smoke, and dust from 1991 to 1995. The results were estimated based on the 1992, 1994, and 1996 China Environmental Yearbooks. The pollution intensity for each pollutant is expressed in the unit of kg per RMB 1000, or U.S. $120, (according to the money value in 1990). The estimates are based on the sample sizes of 67,820 factories in 1991, 64,538 factories in 1993, and 65,736 factories in 1995.

As Table I-2 illustrates, national SO_2 emissions over the last twenty years have trended down for those emissions sources covered by the data (generally, large state-owned industrial facilities, with increasing coverage over time that includes smaller, non-state owned facilities). SO_2 emissions have increased from 16 million metric tons in 1980 to approximately 19 million metric tons in 1999; an increase of about 16 percent. However, 3.8 million metric tons (an amount greater than the total increase) of 1999 emissions were attributable to Township & Village Enterprises (TVEs), a source that, while much less significant then, was not even monitored in 1980.

The complexity of this table and the need for explanation and notation regarding the components of this inventory are themselves indicative of the difficulty of inventory development in China. Before 1991, emissions data for the "industry" category included all state-owned enterprises owned by county level governments and above engaged in production activities (i.e., not just industrial enterprises). However, in and after 1991, this figure covered only industrial enterprises and did not include enterprises in other sectors. In addition, totals before 1995 exclude TVEs, which are smaller-scale mostly rural enterprises that are administered below the county government level (or are, in some cases, privately owned). The industrial series for "county level and above" goes back farther than for total industry and the number of enterprises covered has changed significantly. In 1996, the "county level and above" category covered nearly 63,000 enterprises, while in 1999 only 46,000 were included. The 1999 figures for "total industry" include data collected from the "county-level and above" enterprises, as well as data from 25,000 township and enterprises, plus SEPA's estimates for emissions from other industrial enterprises based on production data and estimated emissions factors. Household emissions figures (which also apparently include other non-industrial emissions besides households) were calculated by SEPA based on household sector coal use and emissions factors estimated from survey data on sulfur and ash content of coal. Non-combustion industrial emissions data are calculated from direct measurements, mass balances, or empirical equations. Through 1997, the combustion/non-combustion breakdown is for county-plus level enterprises only; thereafter, it includes township and village enterprises also.

Table I-2. National Sulfur Dioxide Emissions
(million metric tons)

Year	Total	% Growth	Households	Total Industry	Industrial Combustion	Non-Combustion	County Level and above	Township & Village Industry
1980	16							
1985	13.24	-4%						
1986	12.5	-6%						
1987	14.12	13%						
1988	15.23	8%						
1989	15.64	3%						
1990	14.95	-4%						
1991	16.22	8%	4.57				11.65	
1992	16.85	4%	3.62		11.24	1.98	13.23	
1993	17.95	7%	5.03		10.75	2.18	12.92	
1994	18.25	2%	4.84		11.23	2.18	13.41	
1995	23.7	-0.2%	4.16	19.54	11.76	2.29	14.05	5.49
1996	23.57	-1%			11.77	1.86	13.64	
1997	22.66	-4%	4.94	17.72	11.84	1.79	13.63	4.09
1998	20.91	-8%	4.97	15.94	13.89	2.05	12.1	3.84
1999	18.57	-11%	3.97	14.6	12.65	1.95	10.78	3.82

Source: China Energy Databook v5.0, Fridley et. al., LBNL/ERI, Table 8B.2. **Original sources**: EB, China Environmenal Yearbook, various years; SSB, China Statistical Yearbook, various years; CCTV, 2000; SEPA, 1999. Note that the growth rate shown for 1995 excludes Township & Village Industries in order to make the scope of emissions for that year comparable with the previous year.

Table I-3. National Particulate Matter Emissions, 1980-99
(million metric tons)

Year	Total PM	% Growth	Combustion Particulate Matter							Non-Combustion Industrial Process			
			Total Combus-tion	% Growth	House-holds	Industry	County Level and above	% Growth	Township & Village industry	Industrial non-Combustion	County Level and above	% Growth	Township & Village industry
1980	14.85		14.85										
1985	26	12%	12.95	-3%							13.05		
1986	25.54	-2%	13.84	7%							11.7	-10%	
1987	24.49	-4%	14.45	4%							10.04	-14%	
1988	25.62	5%	14.36	-1%							11.26	12%	
1989	22.38	-13%	13.98	-3%							8.4	-25%	
1990	21.05	-6%	13.24	-5%							7.81	-7%	
1991	18.93	-10%	13.14	-1%	4.69		8.45				5.79	-26%	
1992	19.9	5%	14.14	8%	5.44		8.7	3%			5.76	-1%	
1993	20.33	2%	14.16	0%	5.36		8.8	1%			6.17	7%	
1994	19.97	-2%	14.14	0%	6.07		8.07	-8%			5.83	-6%	
1995	44.68	6%	24.71	5%	6.4	18.31	8.38	4%	9.93	19.97	6.39	10%	13.58
1996	N/A	N/A	N/A	N/A	N/A	N/A	7.58	-10%	N/A	N/A	5.62	-12%	N/A
1997	30.78	N/A	15.73	N/A	3.08	12.65	6.85	-10%	5.8	15.05	5.48	-2%	9.57
1998	27.77	-10%	14.55	-8%	2.76	11.79	6.8	-1%	4.99	13.22	5.06	-8%	8.16
1999	23.34	-16%	11.59	-20%	2.06	9.53	5.57	-18%	3.96	11.75	4.58	-9%	7.17

Source: China Energy Databook v5.0, Fridley et. al., LBNL/ERI, Table 8B.2. Growth rates for 1995 exclude Township and Village enterprises for comparability purposes. Total particulate matter includes only those emissions for which data is available, and levels are therefore not comparable from year to year.

Table I-3 shows particulate matter emissions from 1980-1999. In this table, in addition to the qualifications and definitions described above, further definitions are necessary. Particulates from combustion refers to the Chinese term yanchen, which literally means "smoke dust" (a term that is often used to describe particulate matter). Non-combustion particulate matter ("fenchen") refers to particulates released during industrial production processes (e.g., grinding and sorting) and is calculated as emissions gas volume times particulate density at the outlet times duration of operation. The definition of total emissions changed in 1995, which was the first year in which emissions estimates for township and village enterprises were released, and emissions of "particulates from combustion" are therefore very high compared to later years. Total emissions of "particulates from combustion" were 14.78 million metric tons in 1995, according to the pre-1995 definition.

As with SO_2 emissions, Table I-3 also shows a general downward trend in particulate matter emissions from most of the sources covered by available emissions data (though not as pronounced as with SO_2, and rising in the case of household emissions). Both of these tables are graphically summarized in the Figure I-4, which further illustrates the downward emissions trends for the emissions sources covered.

Figure I-5 below presents this information graphically, showing the trends in major pollutant emissions (China Energy Databook Figure 8B.2, China Environment Yearbook, 2000.)

Tables I-4, I-5, and I-6 provide detail on the regional breakdown of SO_2 and particulate matter emissions throughout China for the years 1993, 1998, and 1999, respectively. Figures I-6 and I-7 show the industrial sector breakdown of SO_2 and particulate matter emissions respectively for 1998.

Figure I-5. Trends in Major Pollutant Emissions (Source: LBNL China Energy Databook, SEPA)

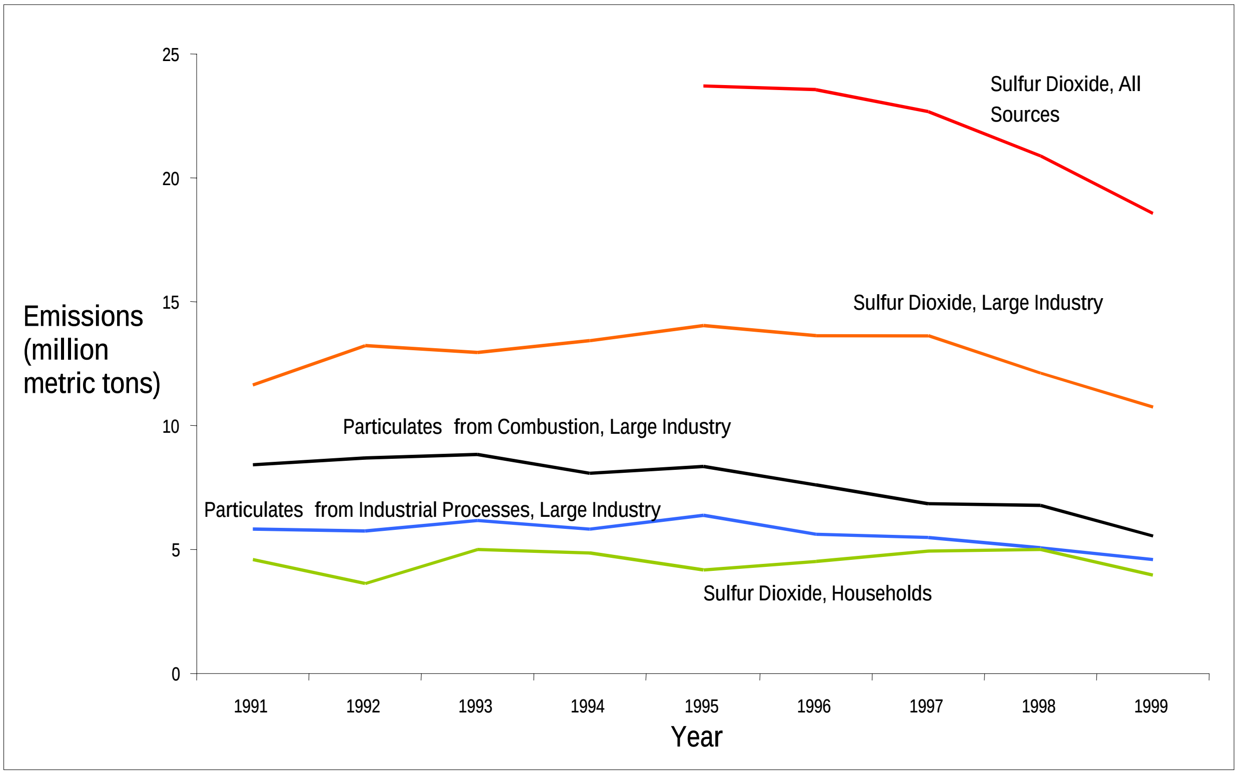


Table I-4. Sulfur Dioxide and Particulate Emissions, 1993

		Sulfur Dioxide			Particulates from Combustion[4]		Particulates from			
Planning Region	Province	Total[1] (kt)	Industry[2] (kt)	Non-Combustion[3] (kt)	Total (kt)	Industry[5] (kt)	Industrial Processes[5,6] (non-combustion) (kt)	Provincial Area (thousand km2)	Sulfur Dioxide Emissions Density (t/km2-yr)	Particulate Emissions Density (t/km2-yr)
North	Beijing	*366*	204	18	*261*	109	64	17	21.80	19.40
	Tianjin	*238*	176	6	*173*	73	37	11	21.03	18.61
	Hebei	*1,021*	860	131	*693*	460	407	188	5.43	5.85
	Shanxi	*1,329*	615	102	*837*	332	219	156	8.51	6.76
	Inner Mongolia	*658*	434	105	*736*	387	174	1,200	0.55	0.76
Northeast	Liaoning	*1,081*	823	199	*1,069*	653	597	146	7.42	11.43
	Jilin	*286*	188	42	*686*	642	112	138	2.07	5.78
	Heilongjiang	*322*	219	16	*1,279*	467	186	473	0.68	3.09
East	Shanghai	*441*	357	22	*189*	148	66	6	71.16	41.14
	Jiangsu	*1,200*	914	127	*757*	581	284	103	11.70	10.15
	Zhejiang	*536*	417	50	*289*	184	219	102	5.27	4.99
	Anhui	*444*	341	87	*641*	243	198	140	3.18	6.01
	Fujian	*184*	154	14	*80*	72	151	122	1.51	1.90
	Jiangxi	*343*	247	35	*338*	282	271	167	2.05	3.65
	Shandong	*2,280*	1,376	160	*1,348*	525	336	153	14.89	11.00
South-Central	Henan	*519*	409	45	*613*	439	290	167	3.11	5.41
	Hubei	*488*	383	117	*439*	230	260	188	2.60	3.72
	Hunan	*528*	515	112	*275*	270	305	210	2.51	2.76
	Guangdong	*543*	508	86	*264*	243	532	178	3.05	4.47
	Guangxi	*655*	522	58	*337*	249	188	231	2.84	2.28
	Hainan	*25*	24	3	*17*	12	12	34	0.72	0.85
Southwest	Sichuan	*1,784*	1,194	198	*1,015*	1,238	512	567	3.15	2.69
	Guizhou	*737*	585	108	*347*	236	156	176	4.18	2.85
	Yunnan	*316*	259	68	*257*	181	127	392	0.80	0.98
	Xizang (Tibet)	*1.9*	1.7	0.0	*0.1*	0.1	15	1,183	0.002	0.012
Northwest	Shaanxi	*668*	560	43	*523*	383	136	205	3.26	3.22
	Gansu	*389*	338	187	*207*	149	141	455	0.86	0.76
	Qinghai	*24*	17	21	*90*	42	27	779	0.03	0.15
	Ningxia	*238*	164	7	*136*	109	59	66	3.61	2.95
	Xinjiang	*305*	135	26	*267*	164	86	1,635	0.19	0.22
National Total/Average		*17,948*	*12,925*	*2,179*	*14,163*	*8,804*	*6,166*	*9,586*	*1.87*	*2.12*
Balance		*305*	125	7	*267*	-136	86	1,635		

Table I-5. Sulfur Dioxide and Particulate Emissions, 1998

		Sulfur Dioxide			Particulates from Combustion[4]		Particulates from			
Planning Region	Province	Total[1] (kt)	Industry[2] (kt)	Non-Combustion[3] (kt)	Total (kt)	Industry[5] (kt)	Industrial Processes[5,6] (non-combustion) (kt)	Provincial Area (thousand km2)	Sulfur Dioxide Emissions Density (t/km2-yr)	Particulate Emissions Density (t/km2-yr)
North	Beijing	*305*	193	8	*121*	83	95	17	11.48	12.88
	Tianjin	*230*	200	4	*97*	80	26	11	17.73	10.89
	Hebei	*1,403*	1,212	210	*1,032*	792	1,006	188	6.45	10.84
	Shanxi	*1,420*	1,100	108	*1,827*	1,314	802	156	7.05	16.84
	Inner Mongolia	*728*	569	66	*570*	362	203	1,200	0.47	0.64
Northeast	Liaoning	*992*	752	115	*891*	751	577	146	5.16	10.07
	Jilin	*284*	212	23	*457*	361	159	138	1.53	4.46
	Heilongjiang	*300*	222	10	*543*	445	124	473	0.47	1.41
East	Shanghai	*489*	391	19	*156*	107	101	6	63.04	41.56
	Jiangsu	*1,255*	1,216	77	*534*	518	549	103	11.85	10.55
	Zhejiang	*660*	625	69	*369*	352	708	102	6.14	10.58
	Anhui	*424*	379	80	*342*	310	585	140	2.72	6.65
	Fujian	*165*	155	23	*99*	89	459	122	1.28	4.60
	Jiangxi	*305*	244	24	*178*	170	374	167	1.46	3.31
	Shandong	*2,259*	1,760	99	*919*	785	925	153	11.50	12.05
South-Central	Henan	*1,003*	768	101	*648*	612	966	167	4.60	9.67
	Hubei	*569*	492	115	*322*	278	605	188	2.62	4.95
	Hunan	*722*	619	157	*450*	410	874	210	2.95	6.30
	Guangdong	*679*	643	74	*342*	324	922	178	3.61	7.10
	Guangxi	*701*	643	82	*436*	402	614	231	2.79	4.55
	Hainan	*20*	20	3	*21*	21	28	34	0.59	1.44
Southwest	Chongqing	*680*	364	28	*273*	129	223	82	8.26	6.01
	Sichuan	*1,408*	718	139	*1,792*	1,433	705	485	2.90	5.15

Table I-5. Sulfur Dioxide and Particulate Emissions, 1998

Planning Region	Province	Sulfur Dioxide Total[1] (kt)	Sulfur Dioxide Industry[2] (kt)	Non-Combustion[3] (kt)	Particulates from Combustion[4] Total (kt)	Particulates from Combustion[4] Industry[5] (kt)	Particulates from Industrial Processes[5,6] (non-combustion) (kt)	Provincial Area (thousand km2)	Sulfur Dioxide Emissions Density (t/km2-yr)	Particulate Emissions Density (t/km2-yr)
	Guizhou	*1,928*	852	72	*672*	473	441	176	10.94	6.31
	Yunnan	*360*	307	76	*355*	312	207	392	0.92	1.43
	Xizang (Tibet)	*1*	1	1	*5*	5	17	1,183	0.00	0.02
Northwest	Shaanxi	*660*	561	51	*438*	397	447	205	3.22	4.32
	Gansu	*383*	332	171	*228*	189	163	455	0.84	0.86
	Qinghai	*31*	20	4	*77*	60	83	779	0.04	0.21
	Ningxia	*215*	186	9	*101*	83	75	66	3.26	2.66
	Xinjiang	*336*	191	35	*255*	135	148	1,635	0.21	0.25
National Total/Average		20,914	15,944	2,053	14,551	11,785	13,212	9,586	2.18	2.90

Table I-6. Sulfur Dioxide and Particulate Emissions, 1999

Planning Region	Province	Sulfur Dioxide Total[1] (kt)	Sulfur Dioxide Industry[2] (kt)	Non-Combustion[3] (kt)	Particulates from Combustion[4] Total (kt)	Particulates from Combustion[4] Industry[5] (kt)	Particulates from Industrial Processes[5,6] (non-combustion) (kt)	Provincial Area (thousand km2)	Sulfur Dioxide Emissions Density (t/km2-yr)
North	Beijing	*233*	162	7	*79*	56	100	17	13.90
	Tianjin	*242*	152	4	*109*	58	21	11	21.45
	Hebei	*1,326*	1,117	173	*914*	714	907	188	7.05
	Shanxi	*1,239*	932	130	*925*	801	617	156	7.94
	Inner Mongolia	*691*	522	62	*550*	347	169	1,200	0.58
Northeast	Liaoning	*937*	724	141	*816*	623	453	146	6.43
	Jilin	*294*	210	49	*387*	307	134	138	2.13
	Heilongjiang	*294*	215	13	*527*	422	118	473	0.62
East	Shanghai	*403*	311	17	*136*	90	41	6	65.02
	Jiangsu	*980*	935	65	*439*	423	458	103	9.55
	Zhejiang	*636*	608	72	*336*	325	690	102	6.25
	Anhui	*410*	364	79	*355*	320	451	140	2.94
	Fujian	*190*	170	17	*97*	80	377	122	1.57
	Jiangxi	*284*	237	29	*190*	185	357	167	1.70
	Shandong	*1,830*	1,452	80	*713*	581	787	153	11.95
South-Central	Henan	*850*	678	91	*756*	658	1,004	167	5.09
	Hubei	*553*	504	110	*336*	309	484	188	2.95
	Hunan	*758*	606	163	*433*	421	784	210	3.61
	Guangdong	*695*	669	81	*347*	335	944	178	3.90
	Guangxi	*583*	548	75	*324*	320	458	231	2.53
	Hainan	*22*	22	4	*22*	22	21	34	0.66
Southwest	Chongqing	*941*	759	38	*236*	141	182	82	11.42
	Sichuan	*813*	526	114	*566*	534	665	485	1.68
	Guizhou	*1,494*	679	65	*569*	402	484	176	8.48
	Yunnan	*337*	277	54	*380*	257	235	392	0.86
	Xizang (Tibet)	*1*	1		*1*	1	3	1,183	0.00
Northwest	Shaanxi	*648*	573	45	*435*	395	394	205	3.16
	Gansu	*312*	257	119	*179*	135	149	455	0.69
	Qinghai	*31*	19	4	*70*	53	64	779	0.04
	Ningxia	*208*	176	13	*118*	92	80	66	3.15
	Xinjiang	*337*	198	34	*244*	125	120	1,635	0.21
National Total/Average		*18,575*	*14,601*	*1,947*	*11,590*	*9,534*	*11,753*	*9,587*	*1.94*

[1] Sum of emissions from industry and households.

[2] From all emissions sources on industrial enterprise premises. Includes electric utilities.

[3] Obtained from direct measurements, mass balances, or empirical equations. This is a subcategory within industrial emissions.

[4] This is a rendering of the Chinese term yanchen, which means literally "smoke dust" .

[5] For 1993-1997, data on particulates in the industrial sector do not include emissions from township and village enterprises, but data for 1998 and 1999 do include emissions from these smaller rural factories. See footnote [1], Table 8B.2.

[6] Solid particulate matter released in the course of production processes (e.g. grinding and sorting). Calculated as emissions gas volume times particulate density at outlet times duration of operation. Enterprises are required to report emissions regardless of whether they meet emissions standards.

Source: China Energy DatabookTable 8B.3.1, 6, and 7. Original source: EB, China Environment Yearbook, 2000.

Figure I-6. SO_2 Emissions by Industrial Sector, 1998 (Kilotons)

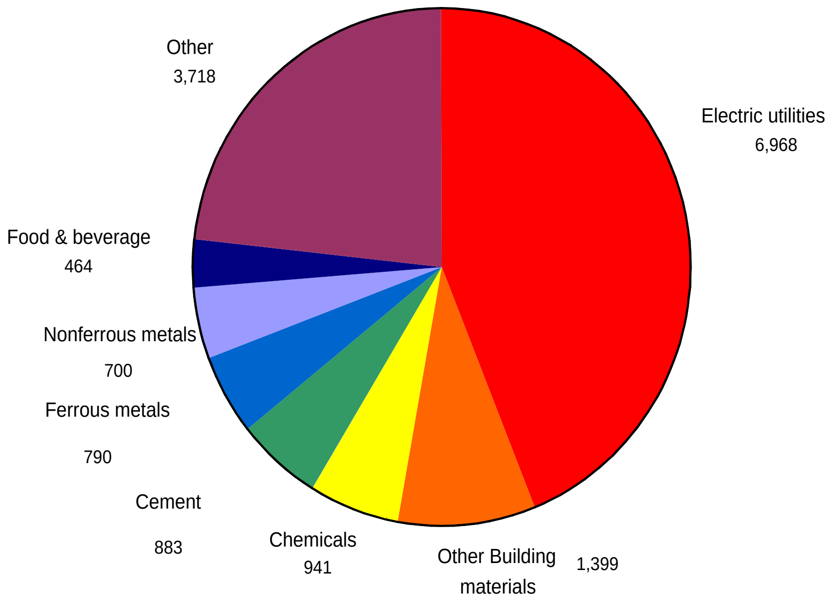
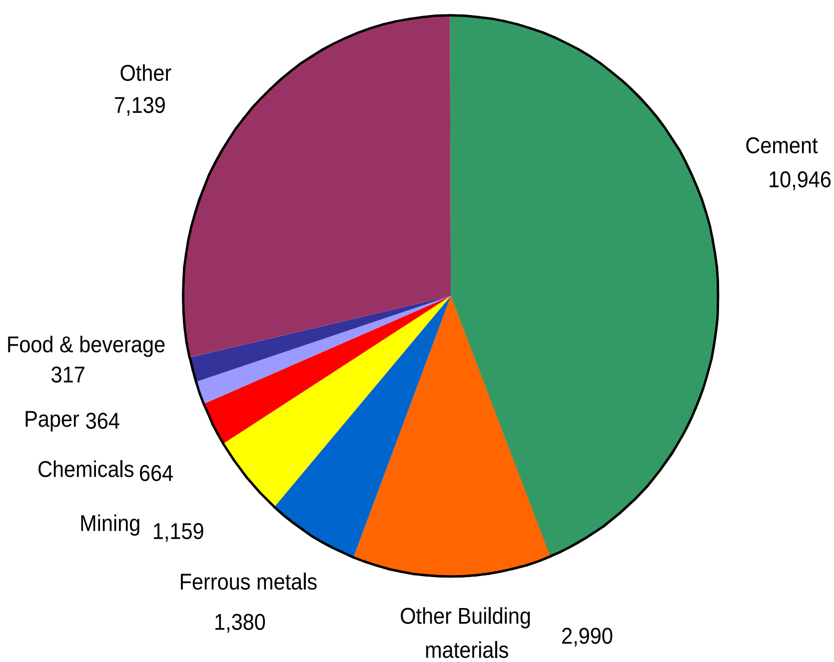


Figure I-7. Particulate Emissions by Industrial Sector, 1998 (Kilotons)



2. Laws, Policy, and Regulations

a. General Environmental Legislation and Policy

The Environmental Protection Law

China began to develop its regulatory framework for environmental management and pollution control just after the first United Nations Conference on Environment in Stockholm in 1972. Today, China's framework is extensive, comprising a vast set of environmental laws, programs, and standards promulgated by the state, provincial, and local governments, all underpinned by the *Environmental Protection Law of the People's Republic of China* (Spofford, 1996).

The Environmental Protection Law was first adopted on a trial basis in 1979, and promulgated as national law on December 26, 1989. This law establishes a series of basic principles and measures for environmental protection. Main principles established in the law include:

- Ensuring that environmental protection programs and systems are developed along with economic development (the “three simultaneous” principle);
- Giving priority to prevention of environmental degradation, and combining prevention and mitigation;
- Comprehensive planning to manage environmental quality, and the incorporation of environmental issues into development plans;
- “Polluter pays,” and the principle that those benefiting from the exploitation of natural resources are responsible for the cost of their protection; and
- Governmental responsibility for environmental quality.

Key systems and programs authorized by the 1989 Environmental Protection Law include:

- An institutional structure and organization for environmental management;
- Establishment of environmental standards;
- An environmental monitoring and on-site inspection system;
- An environmental impact assessment system; and
- A pollutant discharge levy system.

The Ninth Five-Year Plan

The National Ninth Five-Year Plan, established in 1995 to cover the period of 1996-2000, incorporated an extensive set of environmental goals and initiatives, and is an important environmental policy statement. Principal provisions of this plan related to air quality management include:

- The adoption of a “total load control” approach to pollution control. This approach sets limits on the total amount of certain water and air pollutants that can be emitted nationwide in the year 2000, with a target stabilizing the total amount of pollutants discharged in wastewater and emitted to the air at the 1995 level. With regard to air quality, the total load control policy focuses two key air pollutants: TSP and SO_2. Numerical limits are established for overall industrial air emissions of SO_2 and TSP, and industry-specific limits are established for key industries;

- The establishment of air emission treatment efficiency goals for industry. The plan states that TSP removal from air emissions will reach 98% for larger industries and 70% for smaller industries by 2000;
- The renovation of industrial combustion equipment and technology to improve efficiency and reduce emissions;
- The improvement in industrial energy efficiency;
- The development of cleaner industrial energy sources;
- Accelerated controls on SO_2 and TSP emissions from industry; and
- Detailed ambient air quality goals for urban areas. Goals are based on the National Ambient Air Quality Standards (see below), which establish three grade levels for ambient air quality; Grade 3 (least stringent) through Grade 1 (most stringent). The Ninth Five-Year Plan states that by 2000 all urban areas must achieve at least Grade 3 and some must achieve Grade 2 or Grade 1 for TSP, SO_2, and NO_x.

b. Air Quality Legislation – The Air Pollution Control Law

The principal air pollution control legislation in China is *The Law of the People's Republic of China on Air Pollution Prevention and Control* (hereafter referred to as the Air Pollution Control Law). This law was first promulgated on September 5, 1987. It authorized the establishment of:

- National Ambient Air Quality Standards and National Air Pollutant Emission Standards;
- An environmental impact assessment system(precursor to the EIA system eventually incorporated in the 1989 Environmental Protection Law);
- A system of emissions reporting and registration;
- An emission levy system for emissions in excess of standards (precursor to the levy system eventually incorporated in the 1989 Environmental Protection Law);
- Time limits for compliance by industry with environmental standards; and
- A national air quality monitoring network.

Amendments to the Air Pollution Control Law were promulgated on August 25, 1995. These amendments introduced the following initiatives:

- Emphasis on cleaner production, and a policy of phasing out inefficient and highly polluting facilities;
- A switch to clean fuels: reduced use of high-sulfur and high-ash content coal, and an emphasis on using low-sulfur coal, processed coal briquettes, natural gas, and LPG;
- Increased co-generation of heat and other forms of energy;
- Control of acid rain: acid rain and SO_2 control zones were established, and the use of low-sulfur or processed (desulfurized) coal is emphasized; and
- Phase-out of leaded gasoline.

A second set of amendments to the Air Pollution Control Law was promulgated on September 1, 2000. These amendments brought substantial modification of the law.

The current Air Pollution Control Law, as amended, is divided into seven chapters. The following provides a brief overview of the key provisions of the law.

Chapter I – General Provisions

The General Provisions state that government at all levels is responsible for air quality in all areas under their jurisdiction. All entities and individuals have the obligation to protect the air environment and the right to report any infringement by any entity.

The Environment Protection Department of the National State Council is charged with establishing **ambient air quality standards**. Provinces, autonomous regions, and municipalities are allowed to establish supplementary and/or more stringent standards to address air quality issues not specified in the national ambient air quality standards. The Environmental Protection Department of the State Council has to be notified of these supplementary standards "for the record."However, this Department has to approve any local standards for emissions from motor vehicles and vessels that are more stringent than national standards.

The General Provisions provide for special recognition of any entity or individual that achieves outstanding results in the prevention and control of air pollution, or in the protection and improvement of air quality. Such an entity "shall be encouraged and rewarded by the people's government at all levels."

The government is charged with **supporting and encouraging research** on all aspects of air quality management, and also the development of environmental protection industries.

Chapter II – Supervision and Management of the Prevention and Control of Air Pollution

This chapter states, in part that, "Any new construction, expansion or reconstruction project that emits air pollutants…must be in compliance with relevant state provisions concerning the environmental protection for such a project." **Environment impact assessments** must assess the impact of all new projects on air quality as well as identify preventive and control measures to be undertaken. This information must be submitted to the environmental protection departments concerned - which in turn have to inspect and approve any prevention/control facilities before they are put into operation.

Structures emitting substances into the air must declare and **register facilities that emit or treat air pollutants, and the types, quantities and concentrations of pollutants emitted**, with the local environment protection department. All facilities must comply with national and local emission standards.

The Air Pollution Control Law stipulates that a fee **levy system for air pollutant emissions** based on the types and quantities of air pollutants is to be applied to industrial emissions. The charges for the emission of air pollutants are not specified, but are required to be in accordance with the need for strengthening air pollution control, as well as national and technical conditions. Funds raised from this levy system are to be turned in to the state treasury and can only be used for air pollution prevention and control efforts.

The State Council or provincial, municipal, and autonomous regional governments may designate areas that do not meet ambient air quality standards, or acid rain control areas, **as total load control areas**. The State Council is charged with developing special emission regulations for such areas.

No new facilities emitting pollutants into the atmosphere can be established in areas of historical, natural or cultural interest as well as other specially designated areas under national and/or local government protection. The law requires facilities already operating in such areas to treat and control emissions within a set time frame.

The Air Pollution Control Law accords to the State Council the authority to designate and **target key cities for air pollution prevention and control**. Such key cities comprise municipalities directly under the central government, provincial capital cities, open coastal cities and key tourist cities. Key cities that as yet do not meet the relevant air quality standards are to comply within the time limit set by the State Council or the Council's Environment Protection Department.

The Air Pollution Control Law **encourages the adoption of cleaner production and energy efficient technologies** by stating that firms are to give priority to the adoption of these technologies. The State will identify and **phase out older technologies that contribute to high pollution levels**. Such technologies will be banned from production, sale, import, or use after a set time period. The State Council is responsible for drawing up a catalog of processes and production/imports of equipment that are to be phased out.

The Air Pollution Control Law requires the Environment Protection Department to set up a **monitoring system** and establish a unified methodology for monitoring, and affords State and local environmental protection departments the right to conduct **on-site inspections.** All entities and individuals must report and furnish all the necessary information when inspections are carried out. The inspecting department is bound to keep all business matters confidential.

Environment protection departments in large and medium-sized cities are required **to publish regular updates of air quality status** and work toward introducing **air quality forecasting** techniques. Local authorities also have the duty to take compulsory emergency measures in the case of "severe pollution" – defined as pollution threatening human health and safety.

Chapter III – Emissions from Coal Combustion

The Air Pollution Control Law stipulates restrictions on high-sulfur and high-ash content coal. All new mines producing high-sulfur or high-ash coal are to have washing/dressing facilities.

Clean energy usage is encouraged. Key cities may identify areas where highly polluting fuels (as defined by the Environmental Protection Department of the State Council) are prohibited.

The State Council has the authority to stipulate standards and requirements with regard to boiler quality. The Law also calls for an integrated approach to urban planning in order to encourage efficient use of energy resources and systems. City authorities are required to draft plans for the use of cleaner energy by the catering/restaurant industry. Domestic heating and cooking fuel sources are also to be replaced by sulfur free coal or other cleaner sources.

Newly constructed power plants and other enterprises that emit high SO_2 must be fitted with **desulfurization** technologies in order to control sulfur dioxide emissions and remove ash dust.

Firms operating in areas designated as acid rain control areas are required to control air pollution within set time frames.

Safety measures are to be undertaken for coal stockpiling facilities situated in densely populated areas, to prevent possible immediate as well as longer-term air pollution.

Chapter IV – Emissions from Motor Vehicles and Vessels

The Air Pollution Control Law provides for **vehicle emission standards**, and prohibits the manufacture, sale, importation, or use of vehicles emitting pollutants in excess of standards.

The State Council has to approve any application of new pollutant emissions standards or technical retrofitting to motor vehicles implemented by provincial or local governments. Clean energy is to be encouraged by the State and set target dates have to be set by the State Council for the **phasing out of leaded fuel**.

The Air Pollution Control Law allows provincial and local authorities to implement **annual and random emissions inspections of vehicles**.

Chapter V – Prevention and Control of Waste-Gas, Dust and Malodorous Substances

The Air Pollution Control Law strictly limits waste gas and dust emissions. Where such emissions are unavoidable, the pollutants must undergo cleaning treatment. Inflammable gas generated as a by-product is to be recovered for re-use. If this is not possible, pollution prevention and control measures – as in the case of any other pollutant – are applied.

Emission of certain types of gases, such as converter gas, acetylene, phosphoric tail gases and organic hydrocarbon tail gases, **must be reported** to the local government that is responsible for the necessary permits. Plants emitting gas that contains sulfides must install de-sulfurizing facilities or adopt other measures in order to de-sulfurize the gas prior to discharge.

In densely populated areas or other specially protected areas, burning of substances that may produce **toxic fumes or malodorous gases** is not allowed. When transporting or storing toxic gas or dust, hermetic closure or other protective measures are required. Catering facilities are also required to control fumes emanating particularly from cooking oil.

Municipal governments are charged with adopting afforestation and greening programs as a means of controlling dust. Construction sites must use appropriate **dust suppression** measures.

Catering/restaurant operations must control the release of oily smoke from cooking.

Production and importation of **ozone depleting substances** is also subject to production and/or import quotas as determined by the State Council.

Chapter VI – Legal Liabilities

This chapter sets forth a regime of **penalties for violations** of the provisions of the law.

Violators may be **fined** up to RMB 50,000 (U.S. $6,000) for the following violations:

- Refusing to declare relevant facts or submitting false declarations;

- Rejecting on-site inspections;
- Failing to operate pollutant treatment facilities in a proper manner or removal of treatment facilities without permission of the authorities; and
- Failing to install adequate protection measures for coal stockpiles in densely populated areas.

Any entity that has not constructed air pollution prevention facilities or fails to meet the requirements set in national regulations **may be ordered to stop operations**. The entity can concurrently be imposed a fine not less than RMB 10,000 (U.S. $1200) but not greater than RMB 100,000 (U.S. $12,000) by the department that approved the environment impact assessment.

The Air Pollution Control Law requires any entity emitting pollutants above the specified limits to treat the discharge within a set time frame and be imposed a fine not less than RMB 10,000 but not greater than RMB 100,000 by the local government.

Any entity that produces, sells or imports prohibited equipment "shall be ordered for correction by the economic comprehensive administrative department of the people's government." If the violation is serious, a **suspension of business or even a closedown** may be ordered.

Mining of radioactive coal or other forms of coal containing excessive levels of toxic substances, such as arsenic, will result in closure of the mine.

Any entity that continues to use highly polluting fuels shall be ordered to **dismantle the facilities** using the fuel or the **facilities could be confiscated**. A new heating boiler installed in an area already covered by a central heating network shall be ordered to stop and can be imposed a fine not exceeding RMB 50,000. This sanction also applies to any entity testing motor vehicles without the appropriate approval of the authorities.

The Air Pollution Control Law stipulates that violators in the following categories are to rectify their violation. They can be imposed a fine not exceeding RMB 50,000. The categories include:

- Entities emitting dust or malodorous gases which have not taken effective control measures;
- Entities emitting converter gas, acetylene, phosphoric tail gas from electric furnaces and organic hydrocarbon tail gases without prior approval from the local environment protection administrative department;
- Entities transporting and storing potential/actual pollutants without taking the necessary precautions; and
- Catering/restaurant facilities that do not take the necessary measures.

Construction sites that fail to take effective measures to control fly dust will have to implement these measures and be imposed a fine of RMB 20,000 (U.S. $2400). The **project may be suspended** if these orders are not followed and appropriate sanctions will be determined by the local government.

Entities that cause air pollution hazards are obliged to eliminate the hazard and **shoulder the cost of damages** to the direct victim.

Sanctions are specified for any environmental protection department that abuses or misuses pollution levy fees, and for any official that commits abuse of power or negligence of duty with regard to the provisions of the law.

The amended Air Pollution Control Law went into effect on September 1, 2000.

Principal Changes Introduced by the 2000 Air Pollution Control Law

The 2000 amendments introduce the following changes to China's air law:

- Improved enforcement;
- Stricter penalties;
- Clearer lines of authority;
- Focus on air quality problems in key urban areas;
- Emphasis on market-based approaches;
- Shift of emphasis towards total emissions control, and away from control of pollutant concentrations from specific sources;
- Establishment of pollution permits and emissions trading; and
- Expanded coverage – under the old law, control measures were focused almost exclusively on industrial enterprises and power plants, while the revised law includes specific provisions regarding automobiles, ships, domestic heating and cooking stoves, and construction dust.

The amended law gives SEPA new responsibilities including:

- Enforcement of the provisions of the law;
- Assignment of certain responsibilities for designated emissions control zones to provincial environmental protection offices; and
- Establishment of fines and punishments for non-compliance so that fees levied on polluting enterprises are based on the type and total amount of emitted pollutants, and must be set at rates that exceed the cost of abatement.

A set of implementing regulations pursuant to the 1987 Air Pollution Control Law were issued by the State on May 24, 1991. These regulations provide additional detail regarding the implementation of each provision in the 1989 Air Pollution Control Law. However, these regulations do not go to nearly the level of detail generally found in, for example U.S. air quality regulations.

The 1995 and 2000 amendments to the Air Pollution Control Law modify and supersede provisions in the 1991 implementing regulations.

c. Air Quality and Emission Standards

China has established a number of air quality and emission standards, including: ambient air quality standards; emission standards for industrial boilers and kilns; general emission standards for point sources and fugitive emissions; emission standards for specific industries; emission standards for vehicles, and odor standards.

Ambient Air Quality Standards

China's ambient air quality standards were initially issued in 1982 (Standard No. GB 3095-82), and were revised on October 1, 1996 (GB 3095-1996). The standards establish three grades of ambient air quality, and relate them to three types of "ambient air quality objective regions," or air quality functional regions.

Type I region: Natural conservation areas, scenic spots, historical sites, and areas in need of special protection. Grade 1 ambient air quality standards apply in Type 1 regions.

Type II region: Residential areas, mixed areas of residential, commercial, and roadway areas, cultural areas, industrial areas, and rural areas. Grade 2 ambient air quality standards apply in Type II regions.

Type III region: Special industrial areas. Grade 3 ambient air quality standards apply in Type III regions.

GB 3095-1996 states that county-level and municipal-level environmental protection administrations (i.e., Environmental Protection Bureaus or EPBs) are responsible for classifying the areas within their jurisdictions into air quality objective region types, and municipal governments must approve these classifications.

The standards cover ten pollutant types, and specify maximum allowable: annual average, daily (24-hour) average, and 1-hour average ambient air concentration limits for most of these pollutants. Grade 1, 2, and 3 standards are also specified for most of these pollutants. China's ambient air quality standards are presented Table I-7.

Table I-7. China's National Ambient Air Quality Standards (Standard No. GB 3095-1996)

Pollutant	Average period	Concentration Limit			Unit
		Grade 1	Grade 2	Grade 3	
SO_2	Annual average	0.02	0.06	0.10	mg/m^3 (standard state)
	Daily average	0.05	0.15	0.25	
	1-hour average	0.15	0.50	0.70	
TSP	Annual average	0.08	0.20	0.30	
	Daily average	0.12	0.30	0.50	
PM_{10}	Annual average	0.04	0.10	0.15	
	Daily average	0.05	0.15	0.25	
NOx	Annual average	0.05	0.05	0.10	
	Daily average	0.10	0.10	0.15	
	1-hour average	0.15	0.15	0.30	
NO_2	Annual average	0.04	0.04	0.08	
	Daily average	0.08	0.08	0.12	
	1-hour average	0.12	0.12	0.24	
CO	Daily average	4.00	4.00	6.00	
	1-hour average	10.00	10.00	20.00	
O_3	1-hour average	0.12	0.16	0.20	
Pb	Quarterly average	1.50			$\mu g/m^3$ (standard state)
	Annual average	1.00			
benzo[a]pyrene	Daily average	0.01			

Table I-7. China's National Ambient Air Quality Standards (Standard No. GB 3095-1996)

Pollutant	Average period	Concentration Limit			Unit
		Grade 1	Grade 2	Grade 3	
Fluoride	Daily average 1-hour average	7[a] 20[a]			
	Monthly average	1.8[b]	3.0[c]		$\mu g/(dm^2$ day)
	Plant growth season average	1.2[b]	2.0[c]		

[a] Applicable to urban areas.
[b] Applicable to pastoral regions, mixed agriculture and pasture, and sericulture regions.
[c] Applicable to agricultural areas and forest regions.

GB 39095-1996 provides the following details:

- Frequency and duration of sampling required to constitute valid 1-hour, daily, and long-term averages; and
- Analytical methods to be used in determining air concentration levels for each pollutant covered in the standards.

The standards also refer to the guidance document: "Technical Regulations for Environmental Monitoring – Air Monitoring Portion" for specifics on sampling location criteria and probe placement for ambient air monitoring.

General Emission Standards

The general air emission standards in effect in China are the *Integrated Emission Standards of Air Pollutants* (GB 16297-1996), which went into force on January 1, 1997, and replaced a collection of earlier emission standards that had been instituted between 1983 and 1985. These Integrated Emission Standards (IES) stipulate emission standards for 33 kinds of pollutants. Both maximum pollutant concentrations and maximum emission rates are specified.

Maximum pollutant concentrations are specified in mg/m^3. For many of the 33 pollutants covered, separate pollutant concentration standards are specified for particular pollutant subcategory types or sources. For example, within the particulate emission standards there are separate standards for: (1) particulates consisting of carbon black and dye dust; (2) particulates consisting of glass wool, quartz powder, or mineral wool dust; and (3) other particulates. For other pollutants, only a single pollutant concentration standard is specified, applicable to all emissions containing those pollutants.

Three levels of maximum emission rates, Levels I, II, and III, are specified in units of kg/hour. The applicable emission rate standard for a particular source depends on the air quality functional region in which the source is located. Level I emission rate standards apply to any source located in functional region I, Level II standards to any source in functional region II, and Level III to any source in functional region III. IES also provides separate standards for existing sources (i.e., those in existence before January 1, 1997) and new sources (those developed after January 1, 1997). There are only two levels for new sources: Levels II and III. This is because the standards prohibit the establishment of new air emission sources in any air quality functional region I after January 1, 1997 (except new sources for which an EIA had been completed and approved before that date).

Emission rate standards are related to source stack height. For each pollutant and level, a set of emission rate standards are provided for a set of stack heights, with more stringent maximum rates applicable to the lowest stack height (15 m) and successively less stringent standards applicable to higher stacks.

The IES also apply to nonpoint sources (i.e., area sources and fugitive emissions - generally translated as “nonorganized sources” in English-language versions of IES). Detailed instructions are provided for determining the point(s) at which monitoring must be conducted in order to determine whether these nonpoint sources comply with the emission standards.

Pollutants covered in the IES are listed in Box I-1.

Box I-1: Pollutants Included in China’s Integrated Emission Standards

SO_2	xylene
NO_x	phenols
particulates	methyl aldehyde
hydrochloride	acetic aldehyde
chromic acid vapor	acrylonitrile
sulfuric acid vapor	acrolein
fluoride	hydrogen cyanide
chlorine	methanol
lead and lead compounds	anilines
mercury and compounds	chlorobenzenes
cadmium and compounds	nitrobenzenes
beryllium and compounds	chloroethylene
nickel and compounds	benzo[a]pyrene
tin and compounds	phosgene
benzene	bituminous fume
toluene	asbestos dust
total non-methane hydrocarbons	

Industrial Emission Standards

In addition to the IES, six industry-specific and source type-specific emission standards are in place in China. The IES stipulates that in any contradiction between the IES and the industry-specific or source-specific emission standards, the industry-specific or source-specific standards take precedence. Industries or source types for which specific emission standards are in place are listed in Box I-2. The standard number is indicated in parentheses after each standard. The final four digits of the standard number indicate the year in which the standard was issued.

Box I-2: Industries and Source Types Covered by Specific Emission Standards

Coal-fired boilers (GB 13271-1991)
Industrial kilns and furnaces (GB 9078-1996)
Thermal power plants (GB 13223-1996)
Coke ovens (GB 16171-1996)
Cement plants (GB 4915-1996)
Cooking fumes (GWPB5-2000)

As with the IES, these industry- and source- specific emission standards generally provide separate maximum emission levels for the three air quality functional zones types (I, II, and III). Emission standards are presented in terms of maximum emission concentrations, maximum emission rates, maximum emission mass per unit production, and/or the Ringelman visual opacity scale. The standards generally specify different subcategories within each source type. For example, thermal power plants are subcategorized according to whether they have pulverized coal, cyclonic, or fluidized bed boilers, and according to whether they have electrostatic precipitators or other types of particulate controls and provide different maximum emissions for each subcategory. Some of the standards specify separate maximum emission levels for sources located in certain surroundings (e.g. urban or rural areas; rural areas with flat or hilly/mountainous topography). Each industry- or source-specific standard covers the two or three prevalent pollutants in the emissions from the source type, plus (generally) emission visibility (Ringelman opacity).

Vehicle Emission Standards

In 1993, the National Environmental Protection Agency issued vehicle emission standards, and generally updated older standards issued in 1983, 1985, and 1989.

Pollutants regulated for gasoline-engine vehicles are carbon monoxide (CO), hydrocarbons (HC); and NO_x. Test methods for pollutants in exhaust are detailed in separate standards (e.g. GB 11642, GB 14762, GB/T 3845). For light-duty vehicles, for example, methods include dynamometer tests for 13 minutes at 15 engine working conditions (idle, acceleration, steady speed, deceleration, etc.). Maximum emissions are specified in terms of grams per test, or grams per kilowatt-hour of engine output. Similarly, test methods for evaporative emissions are specified, and these emissions are regulated in terms of total emissions per test.

Box I-3: China's Vehicle Emission Standards

Emission Standard for:

- Exhaust Pollutants from Light Vehicles (GB14761.1-93)
- Exhaust Pollutants from Gasoline Engine Vehicles (GB14761.2-93)
- Fuel Evaporative Emissions from Gasoline Engine Vehicles (GB14761.3-93)
- Pollutants from Crankcases of Vehicle Engines (GB14761.4-93)
- Pollutants from Gasoline Engine Vehicles at Idle Speed (GB14761.5-93)
- Smoke from Diesel Engines at Free Acceleration (GB14761.6-93)
- Smoke from Diesel Engines at Full Load (GB14761.7-93)
- Exhaust Emissions from Motorcycles (GB14621-1993)

For diesel engines, "smoke" refers to the total mass captured on a filter using a specified exhaust filtration method. Smoke therefore refers primarily to particulates, but may also include aerosol oils or other fluids captured on the filter. Standards are presented in terms of "smoke value" (calculated from the amount of material captured on the filter using the specified protocol). Diesel exhaust can also be checked visually, and must not exceed the Ringelman level 2 degree of opacity.

Motorcycle standards are similar to those for gasoline engine vehicles. Motorcycles are tested on dynamometers at idle and running speeds, and maximum emission levels are set in terms of pollutant concentration in exhaust (at idle) and pollutant gm/km (running speed). Pollutants regulated are CO and HC. Separate standards are specified for two-stroke and four-stroke engines.

Odor Standards

China's current ambient odor standard is entitled Emission Standards for Odor Pollutants (GB14554-93). It went into effect on January 15, 1994, and replaced earlier standards issued in 1973. As with the Ambient Air Quality Standards (GB 3095-1996), it provides three grades of maximum permissible odor pollution for each of the three air quality functional regions. The standard regulates eight specific pollutants (listed in Box I-4). Emission rate standards are provided for these pollutants in terms of kg/hr. Different maximum emission rates are specified for different stack heights, with more stringent standards applicable to lower stacks.

Box I-4: Specific Pollutants Included in the Emission Standards for Odor Pollutants

ammonia	dimethyl sulfide
trimethylamine	dimethyl disulfide
hydrogen sulfide	carbon disulfide
thio-alcohol	styrene

A general odor standard is also specified, in terms of an odor number (i.e., the dilution factor by which the sample is diluted with odorless air until it becomes odorless). Maximum odor numbers are specified for stack emissions.

The odor standard also provides maximum concentration levels (for the eight specific pollutants) and maximum odor numbers for ambient air at locations downwind of nonpoint sources.

3. China's Air Quality Management Process

This and the next sections address the depth, method, and effectiveness of China's air quality management. The framework for this examination of China's air quality management processes is the series of steps employed in the U.S. for development of air quality policies and programs, and includes:

- Goal setting;
- Emissions inventory;
- Ambient air quality monitoring;
- Air quality modeling;
- Air quality controls identification and policy development;
- Implementation (including compliance and enforcement); and
- Evaluation.

These steps describe a process that has been employed successfully in the U.S. for the establishment of effective air quality management policies and programs. In China, similar to the U.S. and other countries, the national congress and local governments participate in the management and planning process of air quality management. The main responsibilities of the environmental protection administration department of the national congress are setting goals; stipulateing major prevention measures; and reviewing and approving special prevention measures. The main responsibilities of the environmental protection administration department of the national congress are described below.

a. Goal Setting

As discussed previously, a primary mechanism for environmental quality goal setting in China is the process of developing the National Five-Year Plans. The Ninth Five-year Plan (prepared in 1995, to cover the period 1996 – 2000) established a broad and ambitious set of environmental quality goals, among the most important of which was a change in emphasis toward controlling the total load of pollutants released to the environment, and stabilizing this total load at 1995 levels by the year 2000. The Tenth Five-Year Plan (developed in 2000 for the period 2001 – 2005) also contains an extensive set of environmental goals, focusing primarily on water pollution and solid waste, but also including goals for reducing acid rain and air pollution.

The Five-Year Plans are developed at the national level, and ultimately approved by the National People's Congress. A number of national government agencies have input into the development of these plans. Principal agencies involved in developing the environmental aspects of the plans are SEPA (or the National Environmental Protection Agency, as it was called in 1995 when the ninth plan was developed), the State Planning Commission, and the State Economic and Trade Commission. Because the Five-Year Plans, and particularly the Ninth Five-Year Plan, form the basis for the air quality management goals adopted at the municipal level for China's urban areas, the approach and considerations in developing the air quality management goals in the Ninth Five-Year plan are discussed below.

In establishing the air quality management goals embodied in the Ninth Five-Year Plan, many factors were considered, as outlined by NEPA (NEPA et al, 1997) and by Prof. Chai Fahe, Director at CRAES (Chai 2001a). Key factors considered include:

- Recognition that the air quality in China's cities was (at that time) the worst in the world, and posed a significant threat to human health;
- Increasing understanding that deteriorating environmental quality constitutes a constraint on economic development, and therefore that China must move away from an economic growth mode that emphasizes economic growth without due consideration of the environment, toward a mode that fosters environmental protection, sustainable use of resources, and alleviation of environmental degradation caused by the expansion of the economy (NEPA et al, 1997);
- Recognition that rapid economic growth (the Ninth Five-Year Plan included an economic growth target of 8%) and an increasing population would result in increasing pressures on the environment, unless serious efforts were made to integrate environmental protection into economic development (NEPA et al, 1997);
- Recognition that environmental protection is a key issue in international affairs and is becoming incorporated into international trade and investment considerations - and that China must focus on environmental protection in order to be competitive internationally (NEPA, et al 1997);
- Increasing awareness among the general public concerning environmental issues, and increasing public demand for better environmental quality in urban areas (NEPA et al, 1997);
- An assessment of what is achievable given available technology, both current technology in China and best available technology internationally (Chai, 2001a);
- A desire to address the most severe urban air quality problems first, while keeping targets achievable – hence the goals of bringing all urban areas to at least Grade 3 ambient air quality, and some areas to Grade 2 quality. While Grade 3 standards are still not necessarily protective of human health (as compared to U.S. EPA standards, for example, which are more stringent for SO_2 and PM_{10}), goals were set to ensure that the most heavily polluted urban areas (i.e., those not meeting Grade 3 standards) would be addressed, and at least improved to Grade 3 standards (Chai, 2001a; Ren, 2001).
- Assessment of what is achievable economically. It is not deemed economically feasible, for example, to improve the air quality in all of China's cities to the Grade 2 level at this time (Qu, 2000). Environmental goals are set based on what is deemed an achievable, incremental improvement, rather than on levels deemed protective of human health. These would not have been achievable within the time frame of the Ninth Five-Year Plan (Ren, 2001).

Based on these key considerations, as expressed in official documentation and by key authorities, the goal-setting process for urban air quality management at the national level focuses largely on economic considerations (both the economic benefits of improved environmental quality, and the economic costs of the goals under consideration), and on the feasibility and achievability of goals within the planning time frame. Goals selected represent a balance between the desire to improve environmental quality and human health conditions, and the desire to avoid undue economic burden. Absolute issues, such as the level of air quality deemed necessary to protect human health, are given less weight when Grade 3 standards are chosen as targets.

b. Emissions Inventory Development and Use

The air pollutant emission inventory maintained at the national level in China focuses on larger point sources, particularly those associated with coal combustion. The inventory is maintained by CRAES.

Individual emission sources included in the inventory report their data to local EPBs that, in turn, report the information to CRAES. For the largest point sources, for example, electric utility companies, facility managers estimate and report emissions rates or loads. The basis for emission estimation is up to the facility manager, but is generally the rate of coal consumption, and factors for air pollutant emission per unit of coal consumption. For the other point sources, the associated facility management reports operational data to the local EPB, and emissions are estimated based on these data by the receiving EPB (if they have the ability to estimate emissions), or by CRAES.

The inventory maintains data regarding emissions of SO_2 (the main emphasis), NO_x, CO, and particulates – sometimes specified as PM_{10}. The database also includes stack parameters (height, diameter, temperature, flow rate) and latitude and longitude for each source. A 12-digit numerical classification system is applied to point sources. This system is based on process type, although it is not as detailed as, for example, the U.S. Source Category Code (SCC) system (ibid).

The inventory system has only very limited area source emissions estimates. These are primarily developed using per capita emission factors. There is no national mobile source inventory (ibid).

In 1995, SEPA undertook a nationwide survey of industrial installations. A survey form was sent to every industrial installation in the country, including even small enterprises. Each enterprise was required to complete and return the form to the local EPB. The surveys requested a wide array of operational data, including information on atmospheric emissions of “smoke,” dust, CO_2, SO_2, and other pollutants.

SEPA contracted CRAES to collect and compile the survey data into a computer database, which has been done. This database remains probably the most comprehensive national-level body of data regarding industrial air emissions. However, the survey data are recognized to have several shortcomings and to be of limited reliability due to insufficient verification of survey entries provided by industrial managers. This is particularly the case for the data regarding small-scale enterprises (Chai, 2001b).

In 1998 SEPA initiated a follow-up survey, but the data from that survey had not been compiled at the time of writing (ibid).

Air emission inventory data are used to a limited extent in national-level air quality management decision-making. National-level modeling is not carried out to assess ambient air quality (ibid), so inventory data are not used as an input for modeling at the national level.

Inventory data are used as a basis for establishing benchmarks against which future air emission goals are measured. In the development of the Ninth Five-Year Plan, total industrial air emissions, and industrial air emissions by sector and by region of the country were assessed. Some of these nationwide air emission data are cited by NEPA, et al (1997) in the preamble to the Ninth Five-Year Plan “Targets for Environmental Protection” document. That plan establishes the goal of stabilizing the total loads of SO_2 and dust to be emitted by industries nationwide at 1995 levels in the year 2000. The 1995 benchmark level is established based on compiled emissions data for that year.

National-level inventory data also play a role in evaluating success in achieving broad national targets, as discussed in Section G below.

National emission inventory data therefore do play a role in establishing national-level control strategies for air emissions from industry. However, this role differs significantly from that in the U.S.

c. Ambient Air Quality Monitoring and Assessment

Box I-5: Air Quality Monitoring Stations Coordinated by the NEMC

National level:	1
Provincial level:	37
Municipal level:	377
County level:	1,808
Total:	2.223

The China National Environmental Monitoring Center (NEMC - affiliated with SEPA) coordinates a national air quality, monitoring program that compiles monitoring data collected at the provincial, municipal, and county levels of government. The overall system consists of 2,223 monitoring stations (see Box I-5). Aside from running the single national-level monitoring station, NEMC's role consists of: overall management of the system, collecting and compiling data, analyzing data, providing guidelines and technical assistance to monitoring stations within the system, producing publications on air national quality (monthly, quarterly, weekly, and annually), and acting as an information clearinghouse.

Most monitoring stations monitor for TSP, SO_2, and NO_x. A few stations can also monitor for other pollutants included in China's national ambient air quality standards (see Section I.A.2. above)(ibid). A single station in Beijing has the capability to monitor for $PM_{2.5}$. Technical sophistication of monitoring stations varies widely, from manual sampling methods (bubblers and impingers) and manual data compilation in the less sophisticated stations, to continuous monitors, automatic data acquisition systems, and remote telemetry links to a central computer for control and data collection in the more modern stations (e.g., Beijing) (ibid).

Air quality monitoring data is reported to the public via newspapers and other media in China's major urban areas. In 1997, the State Council instituted a requirement that major cities should produce weekly air quality reports using a system unique to China known as the API (Air Pollution Index). The API system evaluates air quality by establishing a relationship between differing concentrations of primary pollutants and their negative effects on human health. Although difficult to compare with U.S. reports, the weekly API air quality reports have stimulated public interest and concern for improved air quality in China (U.S. Embassy Beijing, 1998; East Asian Executive Reports, 2001). By 1999, this program had expanded to daily reporting in 12 cities. On June 5, 2000, SEPA announced that daily reporting of ambient air quality would begin in 47 of the "key" cities (as identified in the Ninth Five-Year Plan).

SEPA has also instituted a major program to modernize and expand the ambient air monitoring capability in China's urban areas. An initial phase of this program, to install updated monitoring equipment in 11 cities, has been completed, and a second phase to install equipment in an additional 33 cities was under way at the time of writing. The stated ultimate goal of this program is to install updated monitoring capability in 600 cities nationwide.

Ambient monitoring data plays a significant role in the establishment of air quality management goals and programs at the national level, and in the evaluation of progress towards these goals. Citing poor ambient air quality in China's cities, the Ninth Five-Year Plan established as a "main target" the achievement of ambient air quality standards for TSP, SO_2, and NO_x in China's cities by 2000. Southern cities were generally targeted to achieve Grade 2 levels for TSP and SO_2, while northern cities were targeted to achieve Grade 3 levels for these pollutants. Cities with populations of less than 1 million were targeted to reach Grade 1 standards for NO_x, while larger cities were targeted to achieve Grade 2 standards for NO_x by 2000 (NEPA et al, 1997). During 2000, as part of the development process for the Tenth Five-Year Plan, success in achieving the goals established in the Ninth Five-Year Plan was assessed. It was determined that Beijing, for example, had achieved its goal of air quality no worse than Grade 3 for 80 percent of the time during 2000. In Beijing between 1998 and 2000, the average daily concentration of TSP had fallen by 7 percent, NO_x had fallen by 18 percent, and SO_2 had fallen by 41 percent. A SEPA official stated that 22 of the 46 other "key" cities emphasized in the Ninth Five-Year Plan had met national air quality standards by the end of 2000 (U.S. Embassy, 2000). These data were a factor in the decision to further reduce key industrial emissions during the 2001-2005 planning period.

d. Air Quality Modeling

Air quality modeling in general in China is in the research and development stage. While basic models such as the Gaussian dispersion models are applied for local-scale assessment of non-reactive pollutants such as TSP and SO_2, the more advanced photochemical air quality models such as the ones used in the U.S. for regulatory purposes are generally not available or in use in China.

One important constraint in applying advanced photochemical grid models (such as U.S. EPA's Models-3, for example) is that the current air emissions inventory data will not support such models. While inventory data are available for major point sources and to a lesser extent for vehicle emissions, current emission inventories provide very little data for area sources. In China's urban areas, small-scale emissions, for example from residential cooking and heating, are a significant source of overall emissions. Any attempt to model urban air quality without adequate area emissions data would produce unreliable results (ibid).

In general, the advanced photochemical air quality models have not yet begun to play an important role in supporting the air quality management process in China. Strategies for achieving the broad urban air quality goal articulated in national policy appear to be developed largely based on a technology-based approach and mostly to address the obvious sources first. However, the emerging (and critical) urban air quality problems associated with the secondary (reactive) pollutants such as ozone and fine PM, which are most detrimental to public health, are not addressed in national policy because of the lack of appropriate tools and capacities.

The "achieve two targets at one stroke" campaign initiated in August 1996 by the State Council provides an example that suggests that modeling may not be widely applied to establish a linkage between control measures and ambient air quality goals. Under this campaign specific goals were set for reducing industrial emissions (more than 238,000 industrial enterprises in the country were required to meet national or local emissions standards by year-end 2000, or face closure, with special attention placed on 18,000 large "key" enterprises, accounting for about two-thirds of total emissions). At the same time, the 47 "key" cities (identified in the Ninth Five-Year Plan) were to meet national standards for ambient air quality by year-end 2000.

Assessments carried out towards the end of 2000 suggested that the first target of the campaign (i.e. industrial emissions control) had been largely achieved in most cities. While nearly half of the cities had achieved the established ambient air quality standards (a very significant accomplishment), the majority had not (U.S. Embassy, 2000). Thus, the prescribed control measures were not completely effective in achieving attainment - suggesting that a linkage between the control measures and attainment had not been thoroughly established through modeling.

In recent years, at least two efforts have been carried out by international institutions, in collaboration with Chinese experts, to model the results of hypothetical policy options on urban air quality on a national scale. These efforts are briefly described below.

Global Environmental Outlook-2000

One of the most recent modeling analyses on air quality in China was conducted in preparation for UNEP's Global Environmental Outlook (GEO)-2000 report by the Asian Institute of Technology (AIT), in collaboration with the National Institute of Environmental Studies (NIES) in Japan. The study, titled "Alternative Policy Study: Reducing Air Pollution in Asian and the Pacific," does not focus exclusively on China, but does provide conclusions regarding managing China's air quality.

The study considers the impact of five broad policy scenarios on air quality through 2030 relative to a 1990 baseline. Specifically, the study modeled the emission levels of SO_2, NO_x, and TSP using a Gaussian dispersion model, under five different policy scenarios: (1) business-as-usual; (2) introduction of cleaner technologies (based on both income-dependent technology acquisition and an accelerated rate); (3) promotion of non-motorized and public transportation; (4) fuel switching and energy efficiency improvements; and (5) a mixture of all three alternative policy scenarios.

The modeling results indicate that emissions levels of SO_2 and NO_x in 2030 under a business-as-usual scenario will be approximately triple the 1990 baseline emissions levels. The study found that the most efficient means of reducing emissions of SO_2, NO_x, and TSP is to combine the accelerated introduction of clean technology with fuel switching.

World Bank Research Department Working Paper (1997)

A 1997 modeling study, "Surviving Success: Policy Reform and the Future of Industrial Pollution in China," was conducted by Susmita Dasgupta, Hua Wang, and David Wheeler, as a World Bank Research Department Working Paper. The study forecasts air pollution concentrations and related health effects in China through 2020, and concludes with an analysis of the benefits and costs of tighter air pollution control. The modeling was performed using the Industrial Pollution Projection System (IPPS), a modeling system that uses industry data to estimate comprehensive profiles of industrial pollution. The modeling was based on data provided by SEPA, from which large-scale econometric exercises were performed.

The paper models China's pollution levels, focusing on SO_2, and TSP under three policy scenarios: (1) business-as-usual; (2) economic reform; and (3) economic reform with stricter regulation in the form of air pollution levy-increases of (a) 5 percent and (b) 10 percent.

Of greatest interest here are the results of the third scenario, examining the response of SO_2, and TSP emissions to air policy options (an increase in air pollution levies), in conjunction with economic reform. Under this option sharp improvements were projected at the national level. The study suggests that with a 5 percent annual increase in air pollution levies (leading to a four-fold increase by 2020), SO_2 and TSP emissions would be reduced to 10.3 million and 7.5 million tons in 2020, from the 1994 level. If the levy increase were raised to 10 percent annually (leading to a thirteen-fold increase by 2020), emissions fall to 6.9 million and 3.6 million tons, respectively. This is equivalent to a 50 percent reduction of SO_2 emissions and a 75 percent reduction of TSP emissions from the 1994 baseline.

The paper concludes with a detailed analysis of the benefits and costs of tighter air pollution control. For a representative Chinese city, Zhengzhou, the study finds that the optimum charge rate for SO_2 emissions is around $90/ton -- fifty times the current rate.

The 2000 Air Pollution Control Law provides the framework for substantial increases in pollution levies (although levels for the new levies are not specified in the law).

e. Air Quality Controls Identification and Policy Development

The role of identifying specific controls to be applied to air pollution sources is shared between the national and municipal levels. As indicated above, national policies and standards prescribe some specific control measures, particularly in the industry-specific and source-specific air emission standards. These standards provide emission limits for different categories of sources, and in some cases specify the types of controls that must be installed on certain sources (e.g., grease traps on exhaust flues at cooking establishments). The air emission standards for vehicles also include very detailed emission limits. Additionally, National policies also prescribe more general emission limits, in terms of concentration, rates, and total loads, for industry in general. As stated above, these control measures have been selected largely through an intuitive approach, involving identifying and controlling sources that clearly contribute very significantly to air quality degradation in urban areas, not based on detailed modeling efforts.

However, the majority of the work in identifying and adopting controls aimed at achieving air quality goals takes place at the municipal and local levels. The responsibility for bringing urban areas into compliance with ambient air quality standards lies with municipal and local governments. This structure is emphasized in the Ninth Five-Year Plan, which states that “all cities will draft an urban environmental protection plan and diligently implement it. The urban environmental protection plan will be incorporated into the Ninth Five-Year Economic and Social Plan, and will be harmonized with the urban construction plan, for each city” (NEPA et al, 1997).

The relative roles of the national and municipal-level governments in establishing air quality-related controls is codified in the Air Pollution Control Act of 2000, which states in Article 3 that: “The local people’s governments at all levels shall be responsible for the air environmental quality in the areas under their jurisdiction, and shall formulate plans and adopt measures to ensure the air environmental quality in the area under their jurisdiction to meet the defined standards.”

Thus, SEPA and the national level of government establish broad guidelines for measures to achieve urban air quality goals. The municipal and local governments prepare detailed plans, including identification of specific control measures (Li, 2001; Wu, 2001). Further discussion of the process of control measure identification is presented below.

f. Implementation

Implementation of air quality controls, as with the identification of specific controls, takes place almost entirely at the municipal and local levels. All monitoring, inspection, and enforcement capability resides at these more local levels of government.

The Air Pollution Control Law of 2000 expands SEPA's administrative authority, by delegating to SEPA new responsibility for implementing and enforcing some nationally mandated air quality controls. It is too early to assess the effect of this change.

Further discussion of implementation actions at the municipal and local levels is presented below.

g. Evaluation of Effectiveness and Modification of Controls

In recent years, increasing effort has been devoted at all levels to assessing the effectiveness of air quality controls. At the national level, in the final years of the Ninth Five Year planning period, considerable evaluation was carried out regarding the extent to which the air quality goals included in that plan had been achieved. Beginning in January 2000, reports on the results of the "two targets" campaign in various localities began appearing in the press, including SEPA's *China Environment News* (U.S. Embassy, 2000).

The general assessment was that most provinces and municipalities throughout China had "basically" achieved Ninth Five-Year Plan targets for controlling total emissions of major pollutants and bringing all industrial enterprises into compliance with environmental standards (aside from roughly 500 large state-owned "pillar" enterprises that were given a two-year extension to meet these standards). Official statistics show improvements in many areas, with approximately half of the 47 cities targeted in the plan meeting applicable ambient air quality standards (ibid).

This general assessment that the country's urban areas were still not achieving the basic air quality standards contributed to the promulgation of the strengthened Air quality Control Act 2000, as well as inclusion of further air quality control measures in the Tenth Five-Year Plan. Thus, while some evaluation of the effectiveness of air quality controls does appear to take place at the national level, this evaluation is of a general nature as is the response to findings. It does not appear that detailed assessment of the effectiveness of specific control measures, identification of specific additional control needs, or development of new control regimes targeted at specific sources, takes place at this level.

4. Interaction of National/Provincial/City Levels of Government on AQM Issues and Concerns

a. Institutional Structure

China's national-level environmental agency, SEPA, is comprised of ten departments and 40 divisions. These departments function to organize and supervise implementation of the Law on Air Pollution Prevention and Control in China. The departments in the general office are:

- Department of Planning and Finance;
- Department of Policy and Regulations;

- Department of Human Resources and Institutional Affairs;
- Department of Science, Technology and Standards;
- Department of Pollution Control;
- Department of Natural and Ecology Conservation;
- Department of Nuclear Safety and Radiation Management;
- Department of Supervision and Management; and
- Department of International Cooperation.

The departments propose administrative regulations, promulgate and issues rules, orders, codes and standards, and execute the specific limited administrative powers. The main functions of the Division of Air and Noise Pollution Control are to:

- Draft policies, regulations, rules and standards on air pollution prevention and control;
- Develop a national plan to control acid rain and sulfur dioxides and supervise implementation;
- Organize testing emissions of new vehicles and guide the local EPBs to test vehicles;
- Guide key cities to comply with air quality standards; and
- Guide efforts to protect the ozone layer.

The Chinese Research Academy of Environmental Sciences (CRAES), a national-level institute affiliated with SEPA, was established to develop and study tools, policies, regulations and standards for SEPA. SEPA also established the Chinese National Environmental Monitoring Center to draft monitoring methods and codes, coordinate a national monitoring network, manage a national environmental monitoring database, and compile air quality status reports.

Directly beneath the national level of government is the provincial level. Several of China's largest municipalities, including Shanghai, are at the same administrative level as provinces. Thus the Shanghai municipal government functions at the provincial level, directly beneath the national government. Beneath the provincial/municipal level is the county/district level (counties and districts are at the same administrative level; counties encompass rural areas, districts encompass sections of inner cities). Counties and districts are further subdivided into subdistricts. Each province, municipality, county, and district has its own government, including, among other divisions, an Environmental Protection Bureau (EPB). EPBs, at the municipal level, such as SEPB, are led by both the municipal government and SEPA. Municipal EPBs may have affiliated research institutes and monitoring centers (e.g., SAES, and the Shanghai Environmental Monitoring Center) which provide technical support to the EPBs.

b. National/Provincial/City Level Roles and Relationships

The responsibilities of the national, municipal, and district levels of government with respect to environmental management is principally policy-making, implementation, and enforcement respectively. The National People's Congress and SEPA establish laws and regulations at the national level. As stated above, exceptions to this can occur in extreme cases. SEPA can appeal cases to the State Council and prevail upon this Council to take administrative action when necessary. This has occurred in a few cases in which large industrial air emission sources were in egregious noncompliance with nationally mandated controls, and local governments were not acting to bring these sources into compliance. However, Such actions are uncommon (Ren, 2001).

Thus, the role of SEPA and the national government with respect to air quality management includes:

- Establishment of overall policy and guidance (e.g., environmental protection targets and policies in the five-year plans);
- Establishment of air quality goals (national ambient air quality standards);
- Development of national-level control measures (integrated emission standards; source-specific emission standards; vehicle emission standards);
- Development of national level programs (e.g., total load control program);
- Review and comment on specific air quality management plans developed at the municipal level; and
- Initiating national-level enforcement actions in extreme cases.

Aside from SEPA's ability to appeal cases to the State Council, the authority to implement air quality management measures resides almost entirely below the national level, at the provincial/municipal level and below. Municipal EPBs are responsible for making sure that: (1) all emission sources within their jurisdictions comply with emission standards; and (2) ambient air quality standards are met throughout their jurisdictions. Municipal EPBs such as SEPB implement these national-level policies through administrative orders. Plans developed by municipal governments must be submitted to SEPA for review, but again, SEPA has no authority to compel modifications to these plans.

Municipal and district EPBs have the administrative authority to enforce air quality control measures and impose sanctions for noncompliance. Sanctions that these local EPBs can impose range from fines to shutting down the operation of air emission sources.

Thus the role of municipal EPBs such as SEPB with respect to air quality management entails:

- Identifying specific control measures and developing air quality management plans specific to their jurisdiction; and
- Implementation of air quality management plans, including enforcement.

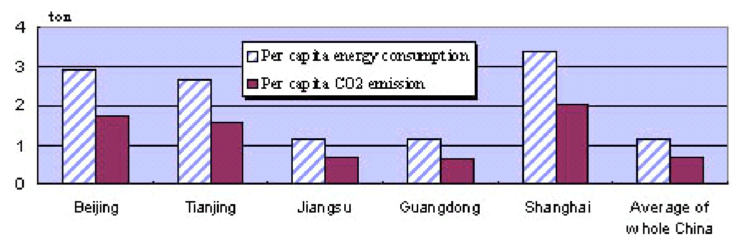
B. SHANGHAI

1. Issues and Trends

Air Quality Status

Compared to other Chinese cities, Shanghai has one of the largest air quality problems (See Figure I-8). The pollution of ambient air in Shanghai is derived from both petrol combustion and coal burning. Specifically, nitrogen oxides (NO_x), total suspended particulates (TSP), sulfur dioxide (SO_2), and dustfall have been identified as the major air pollutants (Shanghai Environmental Bulletin, 2000; Lu, 2001).

Figure I-8. Per Capita Energy Consumption and Emission of CO_2 in Shanghai Ranked First Compared to Other Cities and Provinces in China



(Source: Long, 2001)

Recent Air Quality Tends for TSP, SO_2 and NO_x

In general, TSP and SO_2 in Shanghai have decreased in recent years, while NO_x in the downtown area continues to increase. According to the recent data from 17 auto-monitoring sites, TSP and SO_2 have had a slight decrease. In 1999, the annual average concentration of TSP and SO_2 were 0.175 mg/m^3 and 0.02 mg/m^3, reduced by 0.014mg/m^3 and 0.005 mg/m^3 respectively. In 1999, the annual average NO_x concentration was 0.059 mg/m^3, increased by 0.001 mg/m^3 from the previous year. Average dust deposition was 10.14 tons /km^3 per month, decreased by 1.90 tons/km^3 per month from the previous year.

Air Quality Problems Shift from the Inner City to Rural Areas

Air quality in the center city has improved in recent years, but air pollution in suburban areas has increased, due to industrial programs aimed at moving industries from inner cities to more suburban areas and increasing urbanization and development in previously rural areas. Among the concentrations of air pollutants in Shanghai in 1999 compared to those in 1998, NO_x was 0.001 mg/m^3 higher on a citywide basis, while 0.001 mg/m^3 lower in the urban area and 0.004 mg/m^3 higher in the rural area. TSP was 0.014 mg/m^3 lower on the whole, while 0.047 mg/m^3 lower and 0.005 mg/m^3 higher in the urban and rural areas respectively. SO_2 was 0.005 mg/m^3 lower on the whole, while 0.008 mg/m^3 and 0.001 mg/m^3 lower in the urban and rural areas respectively. Tables I-8 and I-9 contain 1999 and 1998 ambient air concentrations for NO_x, TSP, and SO_2 in Shanghai, respectively.

Table I-8. 1999 Ambient Air Concentrations for NO_x, TSP, and SO_2 in Shanghai (mg/m^3)

Quarter	NO_x			TSP			SO_2		
	Urban	Rural	City-wide	Urban	Rural	City-wide	Urban	Rural	City-wide
1	0.099	0.033	0.062	0.169	0.209	0.202	0.045	0.006	0.023
2	0.082	0.027	0.052	0.153	0.139	0.161	0.032	0.004	0.015
3	0.086	0.027	0.050	0.143	0.092	0.173	0.034	0.003	0.014
4	0.129	0.043	0.070	0.205	0.168	0.200	0.063	0.006	0.027
Annual	0.099	0.033	0.059	0.168	0.152	0.175	0.044	0.005	0.020

Table I-9. 1998 Ambient Air Quality of Shanghai (Long, 2001)

Quarter	NO_x			TSP			SO_2		
	Urban	Suburb	City-wide	Urban	Suburb	City-wide	Urban	Suburb	City-wide
1	0.096	0.030	0.057	0.198	0.167	0.193	0.065	0.007	0.032
2	0.093	0.023	0.052	0.203	0.127	0.178	0.044	0.006	0.021
3	0.088	0.023	0.050	0.183	0.108	0.160	0.042	0.005	0.018
4	0.123	0.040	0.072	0.272	0.184	0.226	0.059	0.006	0.028
Annual	0.100	0.029	0.058	0.215	0.147	0.189	0.053	0.006	0.025
Second grade level in national standard	0.05			0.20			0.06		

In 1998, the coal consumption was 37.58 million tons. The yearly emission of SO_2, smoke dust and industrial dust was 0.489, 0.156, 0.101 million tons, respectively. In 1998, there were 0.6 million automobiles, 0.28 million motorcycles, and 0.4 million of other kinds of vehicles, for a total of 1.28 million vehicles (Lu, 2001).

Air Quality and Emission Statistic

According to air quality daily reports in 1998, and compared with the second class of the national ambient air quality standard, the compliance rate was 100% for SO_2, 95.4% for TSP, and 64.7% for NO_x. NO_x appeared to be the principal pollutant on 217 days, accounting for 59% of the year. For 17 days of the year, the NO_x air pollution index exceeded 200, thus also exceeding the third class level (Lu, 2001).

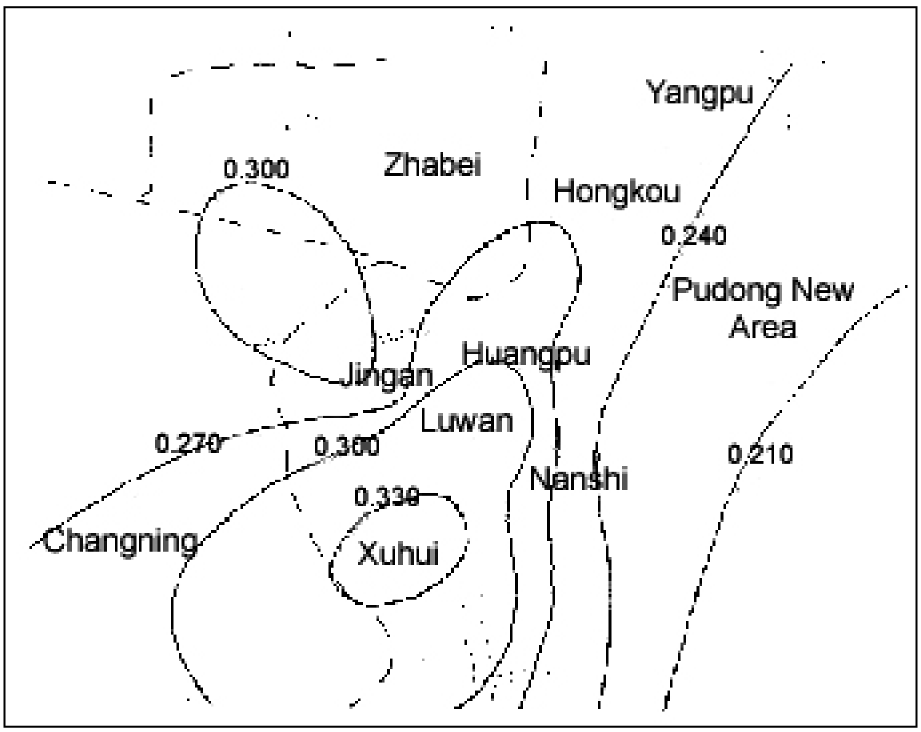
Seasonal and Spatial Variation Trends

Seasonal and spatial variations in air quality trends can be found in air quality data dating back to 1994 (UNESCAP, 1999).

- ***Sulfur dioxide:*** In urban areas, seasonal variations in SO_2 concentrations are relatively higher in winter and spring, and lower in the summer months (June to August). However, In the suburbs and adjacent counties, the seasonal change was insignificant. This seasonal variation in urban areas can be attributed primarily to weather. Specifically, in the winter and spring, inverse temperature layers near the ground and relatively low wind velocities occur frequently in most urban areas of Shanghai, thus making a significant contribution to the annual peak concentration of SO_2. For instance, the average daily concentration of SO_2 was as high as 0.2mg/m^3 when the inverse temperature layer was 500m thick occurred during the last ten days of January 1994. In summer, when Shanghai enters its rainy season, the heavy rains and tropical storms greatly contribute to the lower concentration of SO_2 during that season (UNESCAP, 1999).

- ***Nitrogen oxides**:* The seasonal variation in NO_x is similar to that of SO_2 and can be traced back to the mid-1980s. In fact, when compared with other nearby urban areas, the seasonal NO_x trends are particularly pronounced in ChangNing, YangPu, and HongKou districts (UNESCAP, 1999).
- ***Total Suspended Particulate (TSP)**:* The seasonal variation of TSP is also similar to that of SO_2 and currently affects a large portion of the urban areas in Shanghai (Figure I-9) due to the solid particles caused by the large-scale infrastructure construction and heavy traffic. In the mid-1980s, however, the high TSP concentration only covered the area around the XinHua Road and industrial blocks in the YangPu district. The fact that these two distinct islands of high TSP concentration have now been replaced by a high TSP concentration over the whole city indicates that the cause of TSP pollutants has changed from industrial emissions to particles released by infrastructure construction (UNESCAP, 1999).

Figure I-9. The Spatial Variation of TSP Concentration in Shanghai in 1994 (mg/m^3)



***Dustfall**:* Like the three pollutants mentioned above, dustfall pollution in winter and spring is typically heavier than in summer and autumn. This trend is directly related to weather, and indirectly because of higher coal burning in the colder months. Specifically, the combustible organic matter accounted for approximately 23.8 percent of the content in dustfall. Although dustfall was particularly heavy in three high urban areas of Shanghai (the XingHua Road in ChangNing and LuWan districts, and industrial blocks in YangPu district) in the mid-1980s, more recently the pollution in these areas has been controlled and improved. Today, the new high dustfall areas are located in LongHua in the southwest, and part of ZhaBei district in north (similar to the spatial pattern observed for TSP) (UNESCAP, 1999).

***Other monitoring variables**:* It is noteworthy that in 1994 the concentration of carbon monoxide and lead (Pb) increased. For instance, the average concentration of carbon monoxide increased by 48 percent from 1993. Spatially, the concentration of the two variables is obviously higher in the urban area than in the suburbs and adjacent counties due to the large number of motor vehicles, heavier traffic, and low motor vehicle velocity. In the future, more effort must be made in atmospheric environmental protection in order to control the emissions of motor vehicle exhaust gases (UNESCAP, 1999).

Pollution Generated by Energy Consumption

Because most pollution is derived from energy consumption, a majority of the air quality problems in Shanghai can be traced back to energy use issues and trends (See Table I-10).

Table I-10: Pollution Caused by Generating 1kWh Power of Different Fuel (Long, 2001)

Fuel	SO_2 kg/kWh	NO_2 kg/kWh	TSP kg/kWh	CO_2 kg/kWh	Pulverized Ballast kg/kWh
Coal	9.14	3.32	0.57	1.586	63.01
Oil	6.75	0.68	0.30	0.860	0
Natural Gas	0	0.40	0.06	0.605	0

In general, air pollution in Shanghai was basically dominated by coal use until around 1980. Since then, there has been a rapid increase in the number of motor vehicles, a relocation of coal-using factories from the Inner Ring Road to suburban areas, a transformation of high-pollution industries through end-of-pipe treatment to low-pollution ones, a shut-down of high polluting plants, and a change in sources of energy. This has led to air pollution in the urban districts is gradually becoming a combination of emissions from coal combustion and emissions from motor vehicles, resulting in decreasing levesl of TSP and SO_2, and increasing levels of NO_x and VOCs (CHINA ~ SHANGHAI).

The following section briefly describes energy use and its effects on air quality in Shanghai. Recent shifts in energy sector users and the fuel sources they utilize have had dramatic impacts on air quality over the past decade.

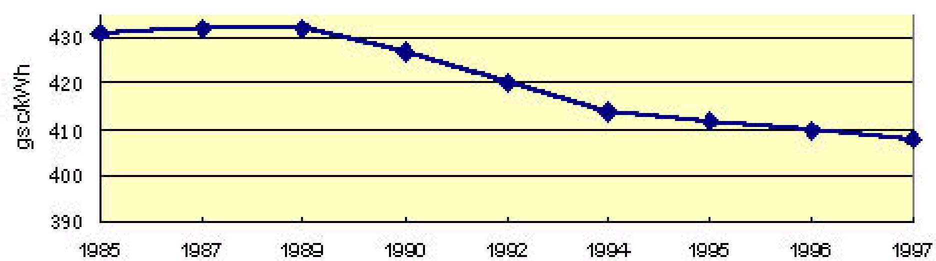
Total Energy Demand by Sector in Shanghai

Research involving energy projection calculations indicates that the final energy demand will reach 1907-2744 PJ by the year 2020 (from 1014 PJ in 1998). The proportion of final energy demand for agriculture to the total final energy demand in Shanghai will reduce 2 percent by the year 2020 (from 2.1 percent in 1998) and for industry will reduce to 49 percent (from 73 percent in 1998). On the other hand, the proportion of commerce, on-road transportation, off-road transportation, and household demand will increase to 18 percent, 14 percent, and 7 percent (from 6.9 percent, 7.7 percent, and 5.3 percent in 1998). Overall, the final energy consumption for 2020 was estimated to be 1.9 – 2.7 times that which occurred in 1998 and appears to have shifted from stationary to mobile sources. (Changhon, et al., 2000). This trend may help to explain recent observations that stationary sources are now responsible for about 60% of total emissions and mobile sources for about 40%. For urban areas, mobile sources are responsible for about 65% and fixed sources (primarily large industrial, or stationary sources) for about 35% (U.S. – China Air Quality Management Assessment Project Meeting, 2001).

Fuel Use Trends in Shanghai

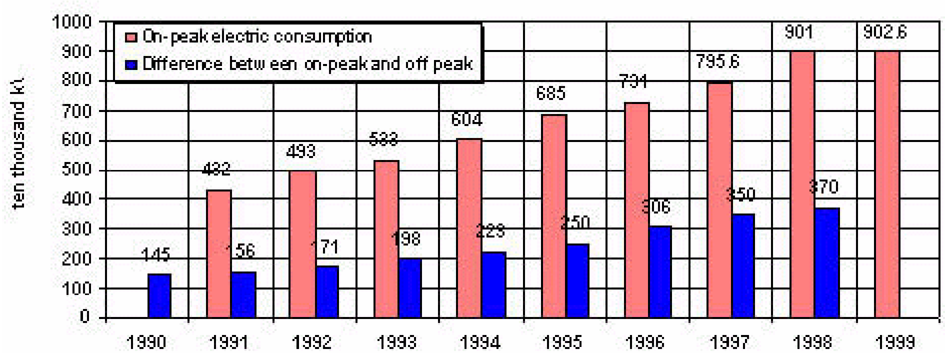
Not only have energy use sectors shifted in recent years, but so have the types of fuels used. For example, coal consumption (historically the main energy source in Shanghai) has decreased over the past decade and only accounted for 76.1 percent of energy consumption in 1998 (See Figure I-10). As a result, the proportion of coal in Shanghai's energy structure has been cut down to 55 percent. However, the use of natural gas is expected to increase to over 10 percent by 2010 (Long, 2001).

Figure I-10. Coal Consumption of Electricity Generation in China (Long, 2001)



Despite shifts in energy use sectors and fuel types, overall energy consumption has continued to increase along with Shanghai's growth and prosperity. For example, electric power demands have increased steadily over the past decade (See Figure I-11) and it has been estimated that the on-peak power demand in the summer of 2000 would reach 9.7-10 million kW (Long, 2001).

Figure I-11. On-Peak Electric Consumption of Shanghai in Summer and Difference Between On-peak and Off-peak (Long, 2001)



a. Air Quality Data

The following is a brief description of recent air quality data for Shanghai's major pollutants: SO_2, NO_x and TSP. In general over the past several years, annual concentrations of SO_2 and TSP have been reduced in Shanghai through pollution control of fuel pollutant content and restrictions on the use of coal. However, these measures have proven to be ineffective in reducing overall NO_x emissions in Shanghai. Furthermore, the continued decrease in fixed industrial pollution sources has made motor vehicles the major contributor to NO_x pollution since 1995. Examples of Shanghai's air quality index and reporting system are also described below. Other air quality information is also provided below including, acid rain, photochemical pollution (the urban heat island effect in Shanghai) and other small particulate matter.

SO_2 Pollution

Over the past several years, annual concentrations of SO_2 have been reduced in Shanghai through pollution control of fuel pollutant content and coal use. The yearly concentration of SO_2 of Shanghai in 1998 was 0.025 mg/m^3 (11 percent lower than that of 1995), and only 0.5 percent of samples failed to meet the daily concentration standard for SO_2. The yearly concentration of SO_2 in the downtown area was 0.52 mg/m^3 (a little bit lower than that of 1995) and 1.3 percent of samples failed to meet with the daily concentration standard. The daily concentration of SO_2 for all of Shanghai was 59 percent lower in 1998 than that of 1986, and for the downtown areas it was 61 percent lower. Concentrations of SO_2 have been in compliance with the Class II national standard for the whole city, while it meets with Class I in the rural area (Changhong, et al., 2000).

NO_x Pollution

Policies and measures for energy and environment mainly focus on coal-burning pollution, and in terms of NO_x pollution, they are ineffective. The monitoring data on daily concentrations of NO_x in the downtown areas from 1986 to 1998 show the deterioration of NO_x pollution since 1995. Daily concentrations of NO_x in the downtown area in 1998 were 0.10 mg/m^3, meeting the Class III national standard. It was 0.028 mg/m^3 higher than that of 1995, and 38 percent of samples failed to meet with the daily concentration standard. For all of Shanghai, the daily concentration of NO_x in 1998 was 35 percent higher than that in 1986, and for the downtown area it was 54 percent higher. With the decrease of fixed industrial pollution sources, motor vehicles became the major contributor to NO_x pollution since 1995, particularly during the months of October and December (Changhong, et al., 2000).

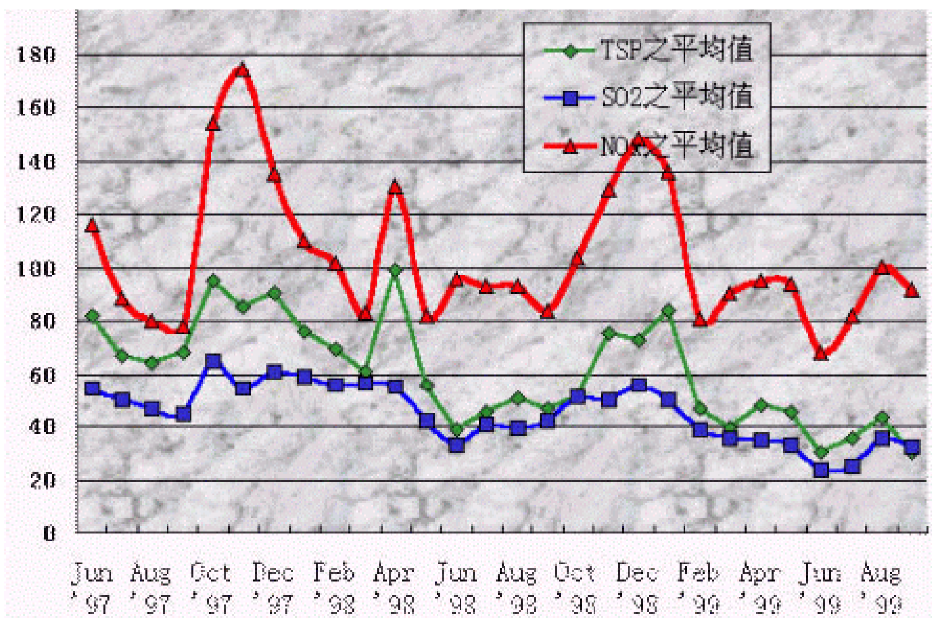
TSP Pollution

With some effective environmental policies, such as popularization of town-gas, the establishment of smoke control zones, and others, TSP concentrations have decreased dramatically. Shanghai's TSP concentrations in 1998 were 33 percent lower than in 1990, and in the downtown area it was 40 percent lower. TSP concentrations for the whole city met with the Class II national ambient air quality standard, while for the downtown area it is near the Class II standard. The highest TSP concentrations can be found in Luwan, Nanshi, and Huangpu Districts and have been steadily increasing in nearby rural areas (Changhong, et al., 2000).

Air Quality Index

Shanghai evaluates air quality using the nationally recognized comprehensive atmospheric index method. Specific pollutants (e.g., SO_2, NO_x, TSP and dustfall) are monitored in the urban area, suburbs, adjacent counties, and in the whole city to calculate air quality indexes (along with pollution load coefficient) to determine the main air pollutant in and around Shanghai. In general, air pollution levels decline from the urban area to the suburbs and then to adjacent counties. Furthermore, pollutant concentration distributions (of which the highest concentration frequently occurs in industrial blocks in the north and south of the central city) are consistent with the industrial allocation. Results indicate that the ranked order of main air pollutants, in urban and suburban areas, is dustfall, TSP, SO_2, and NO_x, respectively. In adjacent counties the order is TSP, dustfall, SO_2, and NO_x, respectively (UNESCAP, 1999) (See Figure I-12).

Figure I-12. Monthly Average Index of Inspecting Data of Atmosphere Air Quality in Shanghai (Long, 2001)



Shanghai Air Quality Data Published on Weekly Basis

Since June 1999, both the Shanghai Environmental Protection Bureau and Meteorological Bureau have jointly released the current and forecast air quality conditions. As a result, both air quality for that day and the predicted air quality for the next day are readily available to the public (via local newspapers, TV, radio and Internet web sites (e.g., Shanghai online). Specifically, the forecast contains information on both the grade and description of air quality indices (e.g., SO_2, NO_x and TSP) (Shanghai Environmental Bulletin, 2000).

Index System for Urban Comprehensive Environment Control

As part of Shanghai's Urban Development and Environmental Protection (UNESCAP, 1999), a series of air quality indices were derived from the general goals and objectives of urban comprehensive environmental control in Shanghai. The goals for environmental protection include the prevention of pollution of SO_2, TSP and dustfall from the use of coal, the prevention of acid rain, and the control of pollution from automobiles. The index system (See Table I-11) established goals for 1993, 2000 and 2010. For SO_2, the standards listed below are all below the Class II national standard of 0.06 mg/m^3, and the 2010 standard is just above the Class I standard of 0.02 mg/m^3.

Table I-11. The Index System of Urban Comprehensive Environment Control in Shanghai

		1993	2000	2010
Indices of urban environmental quality	Annual daily average concentration of TSP (mg/m^3)	0.25	0.20	0.15
	Annual daily average concentration of dustfall ($tons/km^2$ month)	15.8	12	10
	Annual daily average concentration of SO_2 (mg/m^3)	0.05	0.05	0.03

Source: USESCAP, 1999

Other Air Quality Data

- ***Acid rain**:* In 1994, the average pH of rainwater was 5.42 in Shanghai. The frequency of acid rain was 15.9 percent assessed by the national standard (in which the acid rain is defined as having a pH lower than 5.60). The low pH of rain water in winter and spring is consistent with the small precipitation levels in those seasons. Acid rain also shows spatial variations within Shanghai, characterized primarily by two low value areas located around the Jin'an Temple and in HongKou district (partly overlapping the high concentration areas of SO_2 and NO_x). The average ion concentration in rainwater from high to low is: SO_2>Ca_2+>NH+>Cl->NO-, indicating that sulfur oxides and nitrogen oxides are the main constituents in acid rain in Shanghai. Compared with the spatial variation of pH in 1986, these low value areas have become distinctly smaller (UNESCAP, 1999).
- ***Photochemical Pollution – Heat Island Effect in Shanghai**:* Shanghai is a populous industrial metropolis. Its unique urban climate is characterized by the heat island effect, dry island effect and dust island effect, of which heat island effect is the principal cause of the other two conditions. This type of climate strengthens the accumulation of pollutants in the city center, and therefore has a particularly aggravating impact upon air pollution in Shanghai (UNESCAP, 1999) (Figure I-13).

PM_{10}, $PM_{2.5}$

Only limited information about PM_{10} is available for Shanghai, and very limited information is available on $PM_{2.5}$ (See Figure I-14 and Table I-12). This is a concern since these sizes of particulate matter are the most harmful due to their ability to lodge deep in the human respiratory system.

Figure I-13. The Heat Island Effect in Shanghai

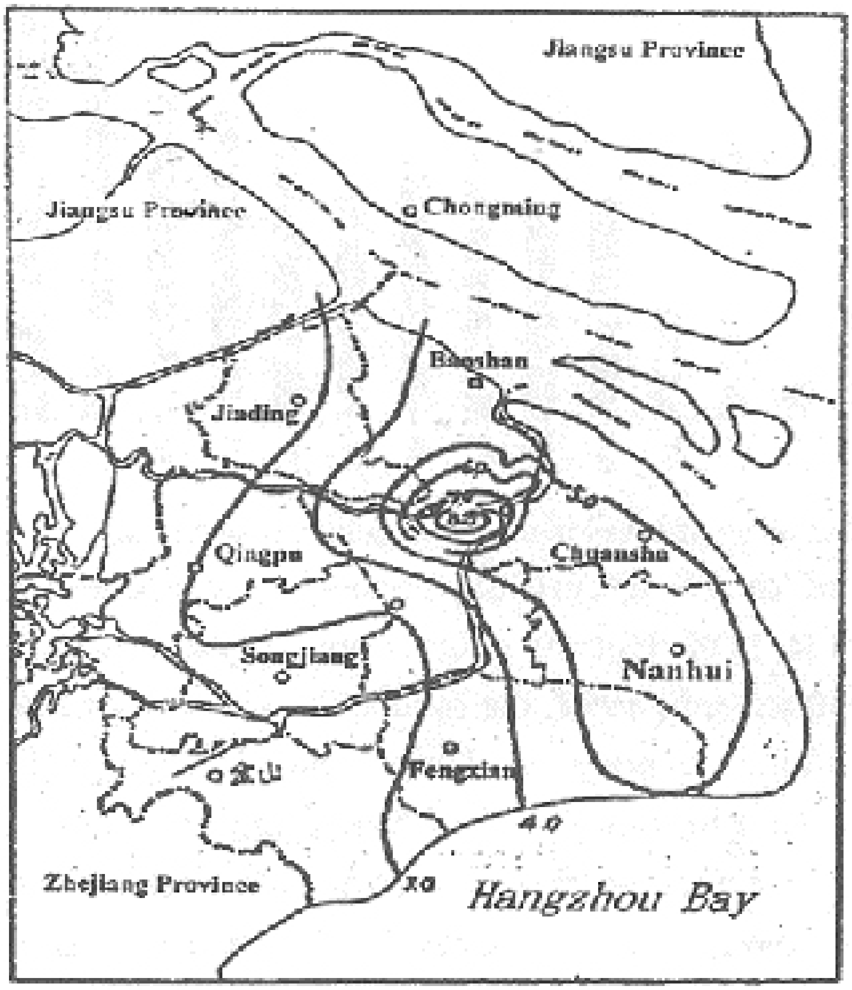


Figure I-14. Relationship Between Indoor and Outdoor PM_{10} (Long, 2001)

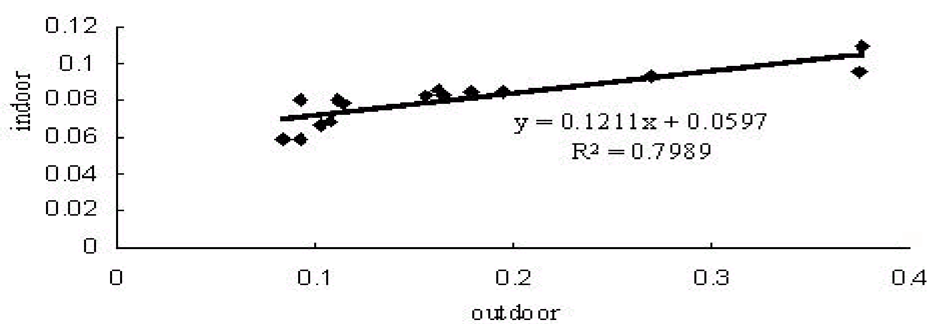


Table I-12: Testing Results of Indoor Air Quality in Seven High-Rise Buildings in Shanghai (Long, 2001)

Building	PM_{10} ($\mu g/m^3$)	CO_2 (ppm)	CO (ppm)	NO_2 (ppm)	CFU (/9 cm•h)
A	51.3(31,564)	729(545,1002)	0	----	70.7(12,1002)
B	59(28,534)	495(423,629)	0	----	18.8(0,36)
C	109(42,585)	666(494,1026)	0	0	73.2(12,192)
D	114(63,422)	970(580,1354)	0	0.15(0.05,0.3)	60.7(0,120)
E	92(64,246)	781(517,1225)	0	0.2(0.1,0.3)	95(24,324)
F	79(40,646)	677(535,1015)	0	0.2	26.5(12,48)
G	317(150,1089)	713(430,1156)	0	0.05(0,0.2)	69.5(12,288)

b. Emissions

To date, only limited air quality emissions data is available for Shanghai. The most recent emissions data derived from the 2000 Shanghai Environmental Bulletin. Other emissions data were derived from model calculations. Both results are described below.

Shanghai Environmental Bulletin, 2000

According to the most recent Shanghai Environmental Bulletin, the coal combustion in Shanghai reached 39.59 million tons in 1999 (5.3 percent higher than in 1998). From that, the total volume of waste gas emissions amounted to 547.95 billion normal m^3 – a majority of which (543.99 billion normal m^3) – can be attributed to industrial sources (see Table 1-13).

Table I-13. Total Loads of Major Pollutants in Waste Gas in 1999 (Shanghai Environmental Bulletin, 2000)

Pollutant	Emissions (t)	Notes
SO_2	403,100 t	in which 310,900 t from industrial sources and 92,200 from domestic sources
Smoke and Dust	137,500 t	in which 90,000 from industrial sources and 45,700 t from domestic sources
Industrial Dust	40,600 t	

Model Emissions

According to recent model calculations (Changhong, et al., 2000), emissions estimates for SO_2, NO_x and CO_2 are as follows:

- **SO_2 Emissions**: In recent years, Shanghai has strictly controlled the sulfur quantity of fuels. Although energy consumption has continued to increase year after year, SO_2 emissions have not increased. Shanghai SO_2 emissions were about 580,000 tons in 1998 (lower than that of 1996 and 1997). SO_2 emissions from power plants account for 50 percent of total SO_2 emissions, other secondary processing and transfer sectors occupy 8 percent, industry 27 percent, tertiary industry 7 percent, and residential use 6 percent. Power plants and industrial sector are still the major sources of SO_2 emissions (Changhong, et al., 2000).
- **NO_x Emissions**: NO_x emissions in Shanghai have increased quickly primarily because the coal burning control measures do not effectively control NO_x emission pollution. Shanghai total NO_x emissions were estimated to be about 400,000 tons in 1998 (up 9 percent, 12 percent, and 14 percent in 1995, 1996, and 1997, respectively). NO_x emission of power plants accounts for 50 percent of total NO_x emissions (other second energy processing

transfer sectors occupies 5 percent, industry 24 percent, road transportation 21 percent, non–road transportation 4 percent, and residential use 2 percent). This increase in NO_x emission in Shanghai from 1995 – 1998 can be attributed primarily to increases in NO_x emissions from motor vehicles. In general, however, major NO_x emission sources are power plants, industry, and transportation (Changhong, et al., 2000).

- **CO_2 Emissions**: According to the study, Shanghai CO_2 emission from mineral fuel burning has been steadily increasing. For example, CO_2 emissions have increased more than 100,000,000 tons since 1994 and reached 130,000,000 in 1998. In 1998, power plants accounted for 29 percent, other secondary energy processing transfer sectors 16 percent, industry 45 percent, transportation 4 percent, residential use 6 percent, and other sources 1 percent (Changhong, et al., 2000).

2. Regulations and Programs

The Shanghai municipal government has been active in the area of air quality management since the 1970s. Action to improve and protect Shanghai's air quality intensified in the second half of the 1990s in response to the National Ninth Five-Year Plan. Regulations and programs that have been established in Shanghai for the purpose of managing the city's air quality are described below.

a. Regulations and Other Policies

As indicated in earlier sections, provincial and municipal governments in China have the authority to promulgate local regulations in response to national-level laws and policies. Shanghai has issued a number of local regulations related to air quality since the mid 1980s. These include:

- Methods for Pollutant Discharge Fee and Fine Management – 1984;
- Environmental Protection Management for Construction Projects – 1988;
- Methods for Soot Emission Management – 1988;
- Rules on Environmental Protection – 1994;
- Rules on Hastening the Adjustment of the Energy Structure – 1999;
- Comprehensive Air Pollutant Emission Standards;
- Quality Standards for Coal;
- Resolution on Strengthening Environmental Protection and Reconstruction in Shanghai;
- Resolution on Adjusting Energy Sources in Shanghai – 1999;
- Emission Standards of Shanghai for Exhaust Pollutants from Light Duty Vehicles – 1999; and
- Rules on Air Pollution Prevention and Control.

In addition, the following regulations and policies are in preparation, or have been passed since 1999:

- Methods for Management and Control of Sulfur Content in Fuel;
- Announcement on Using Clean Energy; and

- Announcement on Transforming Existing Vehicles.

Box I-6 provides an indication of the structure of Shanghai's environmental regulations pertaining to air quality. The programs and control measures instituted by these regulations are described in the following section.

Box I-6 Structure of Shanghai Environmental Regulations Pertaining to Air Quality

Regulations on environmental management	Regulation of environmental planning management
	Regulation of urban environmental management
	Regulation of rural environmental management
	Regulation of environmental protection of ongoing construction projects
	Regulation of comprehensive environmental management
Regulation on pollution management	Regulation of air pollution prevention and control
Regulations regarding procedure	Management measures of mediation in environmental protection
	Management measures of arbitration in environmental protection
	Administrative procedure of enforcement in environmental protection
	Administrative procedure of punishment in environmental protection
	Administrative procedure of re-argument in environmental protection

b. Programs and Control Measures

The earliest measures taken in Shanghai to address air quality began in the 1970s, when the primary source of urban air pollution was coal combustion. An initial measure instituted in that era was to modify the combustion processes in some coal-fired boilers and other facilities to reduce visible emissions.

Measures instituted in the 1980s included (Wang, 2000):

- Requiring particulate removal from the emissions from coal combustion and other industrial processes (removal efficiencies upgraded to 70-80%);
- Moving some of the largest industrial sources of air emissions out of the city center to outlying rural areas within Shanghai Municipality (late 1980s);
- Establishing an emissions charge for industrial emissions exceeding standards (late 1980s);
- Beginning the conversion of household cooking and heating fuels from raw coal to cleaner fuels (e.g., processed coal briquettes, coal gas); and
- Introducing unleaded gasoline in 1987. Shanghai was the second city in China to do so after Beijing.

Since the early 1990s the following additional measures were instituted (Wang, 2000 unless otherwise specified):

- Improvement of technologies in the main air polluting industries such as metal refining, electrical power, and construction materials (including Baoshan Steel Company) to reduce emissions. Advanced production technologies were adopted and emission of TSP and SO_2 were greatly reduced;
- Installation of more efficient dust removal systems in the electrical power utilities (which are coal fired), increasing dust removal efficiencies to 98%;
- Establishment of a coal "quota center" to provide a reliable supply of low-sulfur coal by signing long-term contracts with mining units;

- Closing of small cement factories and improving dust removal efficiencies in air emission streams at larger cement plants; and
- Introduction of an emissions fee and catalytic converters for vehicles (Lu, 2001).

Shanghai intensified efforts to improve air quality in response to the Ninth Five-Year Plan. Measures instituted during the Ninth Five-Year Plan period included (Wang, 2000 unless otherwise specified):

- Establishment of air quality functional zones within the municipality (corresponding to air quality functional regions I, II, and III as described in Section A.2 above), thus establishing ambient air quality standards for all regions of the city;
- Requiring conversion of all coal-fired boilers of less than 1 ton/hour capacity within the center city to use clean fuel, such as piped gas, natural gas, LPG, low-sulfur diesel;
- Requiring conversion of one third of all coal-fired boilers of 1 to 4 ton/hour capacity within the center city to use clean fuel by 2000, and all remaining coal-fired boilers up to 4 ton/hour capacity beginning in 2001 (since 1997 over 3,500 boilers of all sizes up to 4 ton/hr have been converted);
- Requiring coal-fired power plants to switch to coal of 0.8% sulfur (from the former average level of 1.4%);
- Establishment of Near-Zero Coal Use (NZCU), districts in which practically all coal combustion is to be eliminated. Three densely populated districts in the inner city and 11 subdistricts in the outer city had achieved NZCU (as defined by the City government) by 2001, representing 85 km^2 (Wang, 2001b);
- Prohibiting the construction of any new coal-burning facilities in the designated NZCU districts of the city after 2000;
- Expanding the use of centralized heating for at least 6 districts in the city;
- Expanding the conversion of home heating and cooking fuels from coal to clean fuels (largely coal gas). Clean fuels use increased to 98% of households;
- Moving 1,500 coal-fired industrial facilities out of the central city districts, or converting these to non-industrial use by 1999. This reduced the coal combustion intensity in the central city districts from a range of 44,000–75,000 tons/km^2/yr to 11,600 tons/km^2/yr. Industries were moved to outlying rural counties within Shanghai Municipality;
- Introducing flue gas desulphurization in two major coal-fired power plants and 24 medium-sized coal-fired boilers (Shanghai Environmental Bulletin, 2000; UNESCAP, 1999);
- From July 1, 1999, implementation of exhaust emission standards for light vehicles equivalent to the European No. 1 ("Euro 1") standards: restriction of new car sales in Shanghai to a list of vehicle models that meet the standards, and implementation of stricter annual emissions inspections and on-road inspections. These measures improved compliance of light vehicles with emission standards to 95%;
- Conversion of 25,000 taxis to LPG fuel, and construction of 35 LPG filling stations;
- Conversion of 300 public buses to CNG fuel;
- Spurring the investment of over RMB 3 billion (U.S. $365 million) to bring approximately 1,000 polluting enterprises into compliance with emissions standards. This resulted in annual reductions of SO_2 emissions by 20,500 tons, and TSP emissions by 21,300 tons; and

- focusing on the development of high-tech and service industries (termed “tertiary industries”), rather than manufacturing industries, to take advantage of the fact that tertiary industries are less energy-intensive and less polluting.

Shanghai is developing a series of new policies, programs, and measures in response to the air quality management goals in the National Tenth Five-Year Plan (2001-05). An overview of the general approaches is provided. Shanghai’s Tenth Five-Year Plan for air quality management will include the following (Wang, 2001b):

- Establishing the goal that the overall average air quality in the city will be at least as good as Grade 2 standards;
- Further optimizing of the industrial structure, including continued relocation of polluting industries out of the city center;
- Further fuel substitution, to make greater use of natural gas and electric power, reducing local coal use. This will be greatly facilitated by the arrival of an abundant supply of natural gas, once the West-East gas pipeline is completed in 2003. Natural gas will increase to 10% of the city’s energy supply, from 1% at present. An additional supply of electrical power is anticipated when the Three Gorges Dam project is completed;
- Expansion of Near Zero Coal Use zones from 85km^2 to 200 km^2;
- Continuing decreases in the sulfur content of coal burned in the city, to a maximum of 1%. Also decreasing the sulfur content in oil;
- Implementation of a more comprehensive motor vehicle inspection & maintenance program, including incentives to replace older vehicles;
- Development of the public transport system, especially subway and light rail;
- Taking measures to achieve the goals of 20% reductions in SO_2 and 10% reductions in NO_x and TSP emissions from the 2000 levels by 2005. Measures will include: capping air emissions (total emissions control) for larger plants, issuing emission permits, and introducing tradable allowances on a gradual basis. For smaller plants emission concentration standards will be more vigorously enforced;
- Increasing industrial emissions charges from the current ineffectual level of RMB 2 (U.S. $0.25) per ton of SO_2, to a level that exceeds actual SO_2 abatement costs;
- Developing additional monitoring capability to assist in implementing the increased control measures;
- Increasing the level of emissions control on coal-fired power plants, including implementation of NO_x control measures and reducing total SO_2 emissions from power plants even as power generation capacity is increased. Power plants will probably have to install desulphurization. Emission trading will be instituted for power plants. Power plants will have to install continuous stack monitoring systems as a basic prerequisite for emissions trading;
- Emphasizing pollution prevention instead of end-of-pipe pollution control in industry;
- Banning the burning of agricultural waste;
- Controlling secondary (fugitive) dust entrainment from construction sites and roads;
- Introduction of stronger controls for emissions from residences and restaurant establishments (e.g. control of oily cooking fumes);

- Strengthening of institutional capacity for implementation, and developing a comprehensive body of regulations. SEPB is preparing Shanghai regulations for the national Air Pollution Control Law of 2000. These regulations have been reviewed by the local NPC and are expected to be issued in the second half of 2001. SEPB is also preparing a very clear set of responsibilities for government divisions on how to implement the air quality plan under the guidance of SEPB. The goal is to make sure each department follows its mandate with regard to air quality management;
- Increasing emphasis on environmental research in developing economic policy; and
- Improving environmental education and public awareness.

Shanghai, therefore, has been and continues to be very active in addressing air quality in the city. The process by which the Shanghai government identifies and develops air quality policies, programs, and control measures is discussed in the following sections.

3. Shanghai's AQM System

a. Air Quality Goal Setting

As indicated in Section I.B.1.a. above, Shanghai has adopted a set of air quality goals. The city has been zoned into air quality functional zones (pristine and residential, general industrial, and heavy industrial zones) corresponding to air quality functional regions I, II, and III as described in Section I.A.2 above. The Shanghai government has adopted the goal of achieving or exceeding the national ambient air quality standards appropriate to each zone. This set of goals was established by Shanghai in the late 1990s for Urban Comprehensive Environmental Control (UNESCAP, 1999).

One impetus for this set of goals was national policies, particularly the National Ambient Air Quality Standards as amended in 1996. In establishing its set of air quality goals, Shanghai developed a plan to implement these national policies (Wu, 2001).

An additional factor leading to the adoption of this set of goals is the fact that public awareness and emphasis on air quality significantly increased during the 1990s. Air quality managers at SEPB observed that even as the city implemented more measures to improve air quality, the public continued to demand better and better air quality (Zhang, 2001). Shanghai's air quality goals were therefore established partly to address this increasing demand for improved air quality, and to describe a regime of air quality zones and levels that would be satisfactory to the public. The zoning scheme and implementation plan were initially developed by SEPB after consulting with stakeholders. The plan was then sent to the municipal government for review and approval. The city also consulted various departments, district governments, and stakeholders. This process involved significant negotiation with the municipal government and stakeholders (Wang, 2001b; Wu, 2001).

A third basis for the adopted set of goals was an air quality study conducted by SEPB. This study looked at air quality in the city and attempted to identify the primary air emission sources causing polluted air conditions. Based on this study, SEPB determined that the three most serious pollutants were SO_2, TSP, and NO_x. Shanghai's air quality goals were established to focus on these three pollutants.

Shanghai formalizes its goals into 5-year plans, coinciding with the national 5-year planning periods. Once 5-year plans are set, the city government then develops annual goals that together will achieve the plan over 5 years. These annual goals are set based on the amount of improvement the government believes it can achieve in each year, although the goals set for Shanghai were impressive. Annual plans also have to be vetted with stakeholders (Wu, 2001).

Another factor that affects goal setting at the municipal level in Shanghai is achievability. As is the case at the national level, Shanghai's goals for air quality are intended to achieve incremental improvement, in steps that are achievable within the planning time frame and the current economic and technological constraints (Ren, 2001). Although the standards are not necessarily based on absolute levels believed to protect human health, many of the standards that Shanghai set are actually even more stringent than the U.S. EPA health based standards.

b. Emissions Inventory Development and Use

Emissions inventory data regarding important air pollutant sources were key in developing Shanghai's air quality management measures (Wang, 2001a). Inventory data was used to identify primary pollutant sources to be targeted for control measures. The Shanghai emissions inventory was developed based largely on self-reporting from industry, on the 1995 industrial survey (described in I.A.3.b above) and on an evaluation of coal consumption data and calculation of emissions. The emission inventory does not account well for non-point sources or vehicle emissions. (Wang, 2001a; Wang, 2001b).

Analysis of the inventory data indicated, for example, that small boilers had the greatest effect on human health as they released very high total emissions at lower release points. SEPB therefore developed a database of all boilers in the city, and instituted the measures described above to gradually phase out all coal-fired boilers of less than 4 tons/hr capacity (Wang, 2001a).

c. Ambient Air Quality Monitoring and Assessment

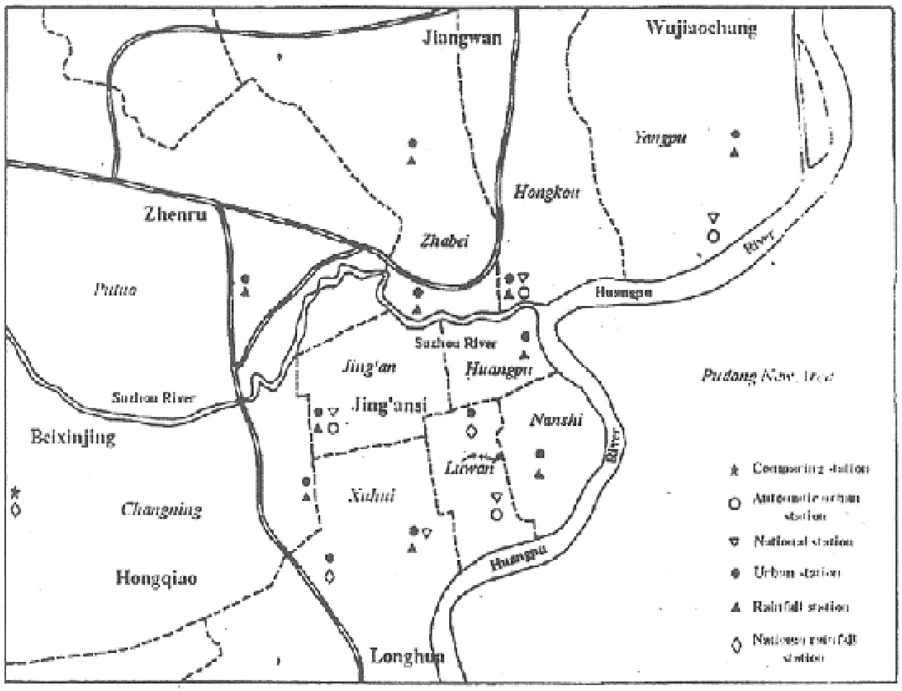
The Shanghai Environmental Monitoring Center (SEMC) undertakes environmental, including air quality, monitoring for Shanghai municipality. SEMC maintains 20 environmental monitoring stations, and provides technical training and assessment to various environmental monitoring stations belonging to the municipal government's departments of industry, agriculture, and water conservancy, and to hundreds of private enterprises. SEMC carries out continuous monitoring of ambient air quality at several sites, and also undertakes irregularly scheduled monitoring to meet special needs such as monitoring key urban construction projects and/or supporting policy-making (UNESCAP, 1999).

SEMC organizes its air quality monitoring activities according to four sub-regions of the municipality: the urban areas, the suburbs, suburban counties, and Pudong New Area. Particular importance is given to the urban areas (ibid).

Air quality variables monitored at SEMC stations are SO_2, NO_x, TSP, the lead content of atmospheric dust, CO, dustfall, percentage of combustibles in dust, sulphuration rate, and fluoride. The pH (along with a number of other chemical and physical parameters) of rainfall is also monitored. Monitoring and analyses are carried out according to procedures defined in national standards (ibid).

SEMC operates a total of 13 automatic continuous monitoring stations: 7 stations in urban areas, 4 in suburban, and 2 in rural areas. The Center also operates 23 manual monitoring stations: 11 urban, 6 suburban, and 6 rural sites (Wang, 2001a). A background monitoring site is maintained in the relatively undeveloped Dianshan Lake area to the west of the city, and provides baseline data for comparison (UNESCAP, 1999). Figures I-14 and I-15 indicate monitoring station locations.

Figure I-15. Map of Air Monitoring Stations in the Urban Areas of Shanghai (UNESCAP, 1999)



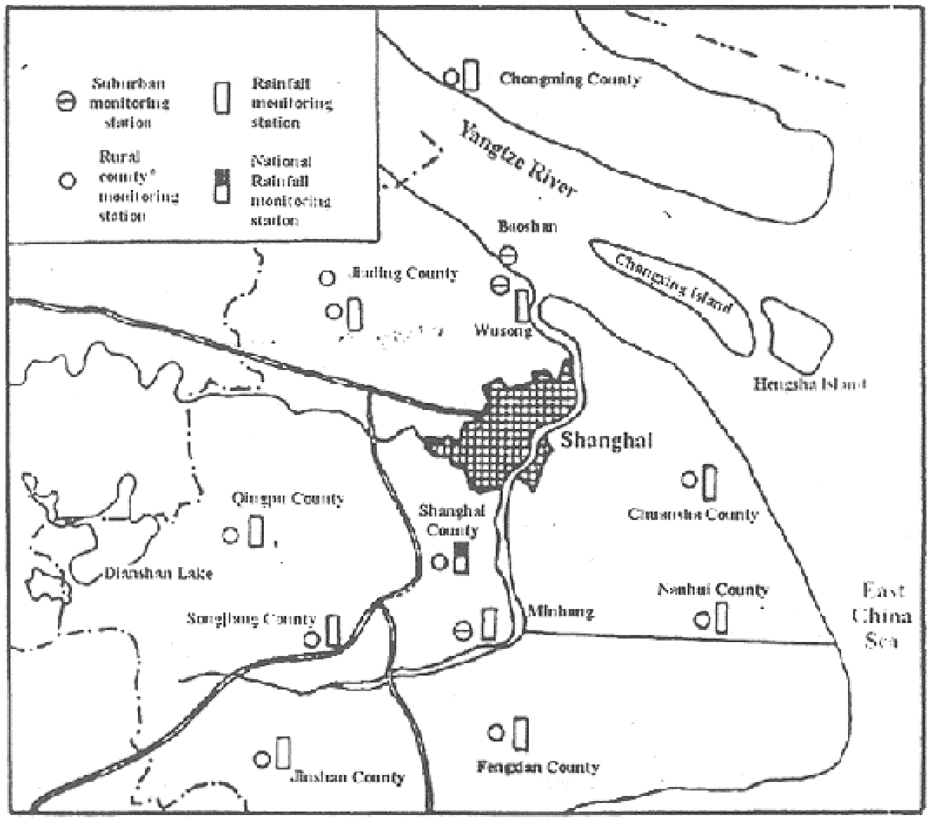
Since October 2000, SEMC has been monitoring PM10 at 7 sites, and also conducting chemical analysis of filtrate. The Center has also recently begun monitoring for ozone at several sites in center and western suburban parking lots.

SEMC also carries out on-site monitoring for special purposes. Examples of this activity include investigations on industrial pollution sources of Shanghai undertaken from 1985 to 1987, environmental impact assessment monitoring of large municipal projects, and comparative monitoring of air quality (and traffic noise) before and after the construction of large road projects. Monitoring activities are also carried out to support the enforcement of environmental laws and regulations. This includes unscheduled monitoring, on-site monitoring of environmental accidents, monitoring to support pollution discharge fee collection, and monitoring to support the implementation of pollution discharge licenses (UNESCAP, 1999).

Each county and district within the municipality also has its own monitoring station(s). The major responsibility of these county and district stations is on-site source monitoring and on-site inspections (Wang, 2001a). Industrial sites are monitored with different frequencies, depending on their characteristics. For example, TSP emissions are monitored annually at boilers of less than 1 ton/hr capacity, and twice annually at boilers of 1-4 tons/hr capacity. At power plants, SEMC carries out annual and random checks. Continuous self-monitoring of stack emissions will be required at power plants beginning in 2002 (Wang, 2001a; Zhang, 2001).

SEMC has extensive computer-based data handling and analysis capability (UNESCAP, 1999). The Center carries out daily reporting of air quality data via the media, using the Air Pollution Index approach which is implemented throughout country (Wang, 2001a).

Figure I-16. Map of Air Monitoring Sites in the Suburbs of Shanghai (UNESCAP, 1999)



The Shanghai government recognizes several weaknesses in its current air quality monitoring capability. The monitoring network has not been able to expand in pace with Shanghai's rapid urbanization and expansion, and the current coverage of the monitoring network is considered inadequate. For example, Pudong (which used to be rural) is now an important industrial zone of approximately 100 km^2, but few monitoring stations are sited there. In addition, the monitoring sites were originally selected mostly to monitor coal combustion emissions, and are not representative of the city as a whole, now that other types of emissions have become important. Coverage of vehicular emissions is not considered adequate, for example. Finally, the SEMC network is unable to monitor comprehensively for several key parameters, including for example O_3, $PM_{2.5}$, and VOCs. The city is working to upgrade its monitoring capability to address these weaknesses (Wang, 2001a).

d. Air Quality Modeling

Air quality modeling is used to some extent by SEPB in developing the city's five-year plans for air quality control and specific air quality control measures (Wu, 2001). An unspecified air quality model was used to determine whether the key control measures in the city's tenth five-year plan (i.e., reducing SO_2 emissions by 20%, and NO_x and TSP emissions by 10% from the

2000 levels by 2005) would allow the city to meet Grade 2 ambient air quality standards citywide by 2005 – the key air quality goal outlined in that same plan. The emission reductions required to meet this goal were determined by modeling the assimilative capacity of various zones within the city, and determining the total emissions that can be allowed within each zone while still meeting Grade 2 ambient standards. These analyses indicated, for example, that 10% reduction in SO_2 emissions would allow the city to meet the Grade 2 ambient SO_2 standard (ibid).

In general, however, the air quality modeling capability at SEPB is basic. SEPB has non-reactive Gaussian plume models, but do not have reactive models (Wang, 2001a). The available models have been linked with the Shanghai Environmental GIS (SEGIS) system, which contains air pollutant emissions inventory data, to provide gridded exposure-level pollutant concentration projections on a $1km^2$ grid (Changhong et. al., 2000).

A modeling exercise to project air emissions in Shanghai under various energy and air quality management scenarios was carried out by the Shanghai Academy of Environmental Sciences (SAES) and Shanghai Medical University (SMU), with support from U.S. EPA, China Council for International Cooperation on Environment and Development, World Resources Institute, and SEPB. This project, entitled the Shanghai Energy Option and Health Impact Assessment, was carried out in late 1999 and early 2000. Current energy supply and consumption, SO_2, NO_x and CO_2 emissions, air pollution levels, and health effects were analyzed. Bottom up energy demand by sector from 2000 to 2020 was projected, based on economic growth and energy demand elasticities. The Markal model (a professional energy optimization model and energy technology system analysis program) was used for energy technology selection, and local air pollution emission and CO_2 emissions were analyzed based on the provisions of proposed energy and environment policies. SEGIS, linked with air pollution dispersion models, was used to provide air pollution exposure level forecasting (Changhong et. al., 2000).

Three energy option and environment policy scenarios were defined in the study (ibid):

- Business as usual (BAU) as a baseline;
- Energy option (EP) scenario involving the following:
  - Limit on coal use to less than 50 Mt;
  - Capacity limit for coal burning power plants to under 12 GW; and
  - Energy shift from coal to natural gas and imported electrical power (based on natural gas from the East China Sea and the West-East gas pipeline, and electrical power from the Qinshan nuclear power station and the Three Gorges project);
- Environmental policy (EP+ENV) scenario involving the following in addition to the provisions from the EP scenario:
  - Establishment of more stringent SO_2 and NO_x emission control targets in 2000 through 2020; and
  - Establishment of different targets for NO_x emissions from mobile and non-mobile sources to compensate for the different exposure impacts of the two source types.

The results show that energy and environment policies can play important roles in air pollutant emission reductions and local air quality improvement, and could provide important co-benefits for human health and CO_2 emission reductions in Shanghai. The EP and EP+ENV scenarios both provided reduced emission rates and improved air quality as compared to the BAU scenario. The model indicated that the current energy policy would greatly reduce the emission of SO_2, NO_x, and CO_2 from 1995 levels, but that these emissions would still not meet total load control objectives. The EP+ENV scenario would achieve total load control objectives for the emissions of these three pollutants (ibid).

In May 2001 the U.S. EPA modeling and emissions inventory experts from the U.S.-China Air Quality Management Assessment team (Carey Jang, and Bill Kuykendal) transferred to SEPB and installed a suite of the latest U.S. EPA public air quality modeling tools, including:

- ISC-3 dispersion model (for simulation of the transport of primary pollutants e.g. CO, SO_x, PM, etc);
- OZIPR/EKMA photochemical box model (for simulation of ozone formation and transport); and
- Models-3/CMAQ (for simulation of multiple pollutants, primary and secondary aerosols, visibility, acid deposition, etc.).

These experts also provided U.S. EPA emissions inventory estimation techniques and overview training on the use of the above models and techniques.

e. Air Quality Controls Identification and Policy Development

As indicated in the foregoing subsections, the process of developing an air quality control strategy in Shanghai involves goal setting, assessment of somewhat limited emissions inventory data, assessment of monitoring data, and basic air quality modeling. Steps in the process, as outlined by SEPB air quality authorities with regard to the decision in the mid-1990s to address small boilers first, included the following (Wang, 2001b):

- Assessment of which pollutants caused the most serious degradation of air quality based on monitoring results;
- Evaluation of coal consumption statistics;
- Calculation of emissions based on coal consumption;
- Evaluation of the effects of the calculated emissions on air quality;
- Evaluation of complaints from the public; and
- Evaluation of the assessment of what controls are feasible under the current economic and technological conditions.

This process led to the conclusions that: (1) SO_2 and NO_x were the worst pollutants and needed attention first, and that TSP was also a serious pollutant that should be addressed; and (2) control strategies should focus initially on small boilers (ibid). This second conclusion was based on the observations that (ibid):

- Small boilers accounted for a high proportion of coal consumption and made the largest overall contribution to air emissions city-wide (small boilers contributed 60% of air emissions);
- Converting small boilers to use clean fuel or eliminating them altogether would address the SO_2 problem, and would also help to address the TSP problem;

- The costs of converting or eliminating small boilers would be relatively small, compared to the air quality benefits gained; and
- Most citizen complaints were about small boilers, which often released highly visible plumes at near exposure heights.

While SEPB recognizes that the finer components of TSP (PM_{10}, $PM_{2.5}$) pose the greatest threat to human health and are likely a problem in Shanghai, the approach to addressing particulates has been formulated based largely on the technical capacity of SEPB. The approach adopted has been to address particulates in a stepwise manner, addressing first TSP, then PM_{10}, and ultimately $PM_{2.5}$, as the agency's monitoring, modeling, and control strategy development capabilities become sufficiently sophisticated to address each component (ibid).

A similar process has been used to develop the control strategies proposed for the tenth five-year planning period, and in response to the Air Pollution Control Law of 2000. One of the key issues addressed in the strategy was compliance with the total emission load controls required under the 2000 law. The law does not specify the manner in which total loads are to be limited, and SEPB was in the process of developing a strategy for this at the time of writing (Ren, 2001).

One of the elements for total emission load control being considered in Shanghai is a cap-and-trade program. SEPB believes this may be the most efficient and effective approach to achieving total emission load limits, but an additional incentive for adopting a cap-and-trade program is that SEPA is encouraging SEPB to pioneer such a program in China. The successful demonstration of such a program in Shanghai would provide SEPA with a sound basis for developing a national regulation calling for the cap-and-trade approach in urban areas nationwide. In order to present such a regulation to the State Council for approval, SEPA must have sound arguments for it. Hence, a pioneer cap-and-trade program in Shanghai could lead to the adoption of this approach nationwide (ibid).

As indicated in the foregoing subsections, the control measure of reducing SO_2 emissions by 20%, and NO_x and TSP emissions by 10% from the 2000 levels by 2005 was adopted on the basis of a basic modeling exercise that indicated that these reductions would allow the city to meet Grade 2 ambient air quality standards citywide by 2005 – the key air quality goal outlined in the city's tenth five-year air quality management plan (Wu, 2001). However, it is recognized that some areas of the city may not be able to achieve the Grade 2 air quality goal for economic reasons (ibid). Thus, goals and control strategies can be adjusted for economic exigencies.

f. Implementation

As indicated in Section I.A.3 above, implementation of environmental policies takes place almost entirely at the local level in China. While SEPA lacks the administrative authority to enforce environmental regulations, municipal governments, such as Shanghai's, have broad administrative authority. Since the mid 1980s, the Shanghai government has implemented through administrative orders, and where necessary through administrative sanctions, numerous air quality control measures.

Implementation of air quality control measures falls to SEPB. SEPB develops plans for air quality management on a five-year planning cycle, and these plans must be submitted to the municipal government for approval. The municipal government consults various departments, district governments, and stakeholders, and approves the plan. Once approved by the municipal government the plan carries the force of municipal regulation, and it becomes the responsibility of SEPB to implement it (Wu, 2001). Measures that affect a specific industry or sector are developed and implemented in close coordination with municipal departments responsible for that industry or sector (ibid).

SEPB can delegate implementation functions to district and county-level EPBs for implementation within their jurisdictions. In implementing the Ninth Five-year Plan, SEPB required the county- and district-level EPBs to ensure that the SO_2 emission reduction goals targeted by 2000 were achieved in their respective jurisdictions by the target date (Wu, 2001).

Measures that SEPB and the district- and county-level EPBs have at their disposal for enforcing regulations and administrative orders range from fines to closure of operations. As an example of implementation activities, during a 1999 push to enforce environmental requirements SEPB and district/county-level EPBs in Shanghai issued a total of 619 administrative penalty verdicts to entities or individuals who were found to be in violation of environmental laws or regulations. At least one industrial facility (Xinhong Dyeing Company) that had discharged a particularly large volume of wastewater in excess of the legal limit was ordered to stop production (Shanghai Environmental Bulletin, 2000). Similarly, in 1995 five unscheduled checks were organized citywide and 771 penalties were handed out, with total fines reaching RMB 2,350,000, or U.S. $285,000 (UNESCAP, 2001).

A weak link in the implementation activities of SEPB and district/county-level EPBs in Shanghai is the limited capacity to monitor all facilities subject to air emission controls on a regular basis, and for all parameters that are subject to control (Wang, 2001a; Zhang, 2001).

g. Evaluation of Effectiveness and Modification of Controls as Necessary

As is the case at the national level, the effectiveness of air quality controls in achieving stated goals is assessed on a gross scale, in concert with the 5-year planning cycle. A general review of the effectiveness of the control strategy implemented during the ninth five-year planning period (1996 – 2000) was carried out towards the end of that period.

At this gross scale, the measures were found to have been largely successful with respect to SO_2 and TSP, for which the annual, citywide average ambient concentration in 2000 met Grade 2 ambient air quality standards. The control measures were found to have been be less successful with respect to NO_x, for which the annual, city-wide average ambient concentration in 2000 did not meet Grade 2 ambient air quality standards (SEPB, as reported in U.S. Embassy 2000). Table I-14 presents the air quality trends in Shanghai over the Ninth Five-Year planning period, compared to China national and WHO standards.

In most cases the appropriate ambient air quality standards for individual air quality functional zones (Levels I, II, and III) delineated within Shanghai were also met, although in a few zones the appropriate standard was not achieved for economic reasons (Wang, 2001b; Wu, 2001)

Although this assessment was carried out, it is not clear to what extent it influenced the development of control measures for Shanghai's Tenth Five-Year air quality management plan.

Table I-14. Air Quality Improvement in Shanghai During the Ninth Five-Year Plan (average concentrations in mg/m^3)

	TSP	SO_2	NO_x
Shanghai:			
1995	246	55	73
1998	215	52	100
2000	155	45	90
China standard*	200	60	50
WHO guideline	90	40	-

*Grade 2 National Ambient Air Quality Standard; Annual Average

Source: SEPB, as presented by U.S. Embassy (2000)

4. Interaction with National and Local Levels, Sectoral Agencies, and Stakeholders

As stated above, implementation authority for air quality management policies and programs in China rests almost entirely at the sub-national level. The level of government directly below the national level (i.e., the Provincial level, or the municipal level in the case of large municipalities like Shanghai) is the highest level of government with administrative authority to implement environmental policy.

The national environmental agency (SEPA) provides guidance regarding policy and programs to the municipal EPB, but has no authority to compel municipal EPBs to follow this guidance. The municipal EPBs prepare air quality management plans based largely on SEPA guidance, and submit these plans to SEPA for review. However, again, SEPA has no authority to modify municipal plans; the national agency can provide only guidance. Despite the fact that SEPA cannot compel municipal governments to comply with its policies, the municipal EPBs do generally strive to adhere to SEPA guidance and policies. Municipal EPB directors and staff consider this to be an indicator of good and successful management, and recognize that divergence from national policy could be unpopular with the local population (Wang, 2000b).

The municipal EPBs receive practically their entire budget from the municipal governments to which they are attached. All plans and proposed actions of the municipal EPBs must be submitted to the overall municipal government for approval. Once the municipal government has approved plans, including air quality management plans, these plans are returned to the EPBs for implementation.

In developing air quality management plans, SEPB consults extensively with other Shanghai municipal government departments, with district and county governments, and with other stakeholders. For example, when air quality measures affect industry, SEPB must consult with the Shanghai Economic and Trade Commission, which manages industry. For vehicle emission measures, SEPB must work with the Public Security Bureau. For measures affecting boilers, SEPB must consult with the companies that own the affected boilers. When air quality management plans are submitted to the Shanghai municipal government for approval, the municipal government also consults with other municipal government departments, with district and county governments, and with other stakeholders in reviewing the plan. Hence SEPB's air quality management plans must be negotiated with and in some cases approved by a range of local stakeholders, requiring considerable negotiation (Wu, 2001).

For these reasons municipal politics occasionally hold control over municipal EPBs, and where EPB actions do diverge from SEPA guidelines, this is often the reason. Municipal governments tend to emphasize development and economic productivity, and cases have occurred where municipal governments have refused to implement (or to allow the local EPB to implement) environmental requirements out of concern that these requirements would reduce productivity or profitability in certain facilities. Thus, municipal EPBs can occasionally be caught between conflicting directives from SEPA and the municipal governments to which they belong. Because municipal governments control the EPBs' budgets, they do have some ability to compel EPBs to follow the municipal governments' directives.

In extreme cases, as noted previously, SEPA can bring matters to the State Council. Decisions of the State Council carry the weight of law, and SEPA has authority to directly implement these decisions. However, intervention by the State Council is rare.

In general, municipal EPBs work to comply with SEPA policies and guidance on air quality management. The EPBs have considerable latitude in how they implement this guidance. Specific control measures are selected and overall air quality management strategies are developed at the municipal level.

Municipal EPBs can delegate responsibility for implementation of air quality management plans to lower levels of government, i.e., to the EPBs at the county, district, and sub-district level. In implementing SO_2 emission reductions under the Ninth Five-Year plan, SEPB divided the implementation effort among the various administrative levels in the city. SEPB passed a directive to each lower-level government EPB regarding the emission reductions to be achieved in their respective jurisdiction, and it became the responsibility of the county, district, and sub-district EPBs to ensure that the emission sources within their jurisdictions complied with the new emission limits. Districts were also made responsible for ensuring that their district complied with the appropriate ambient air quality standards (Wu, 2001). County and district EPBs have administrative authority to implement air quality management programs and enforce compliance with standards. The county and district EPBs carry out much of the on-site inspection and source monitoring effort carried out in Shanghai.

SECTION II. UNITED STATES

A. NATIONAL LEVEL OVERVIEW

The programs and procedures that are currently being applied to manage air quality in the United States are the product of over 30 years of trial and adaptation. The changes have been prompted by advances in the basic understanding of the causes and effects of air pollution as much as by technological advances. This section presents an overview of how the essential components of air quality management are implemented in the United States. As a result of the evolution of the U.S. air quality management program since 1970, there are lessons that can be applied to national air quality management planning in China and other countries. A separate section that provides more details concerning critical aspects of the U.S. program is presented after the overview. The additional section presents a brief historical overview of the evolution of the air quality management process, and addresses the structure of the implementing organizations with a summary of the resources that are applied to make the system work.

1. National Issues and Trends

This section reviews data and trends for air quality and atmospheric emissions in the U.S. Although the Clean Air Act (CAA) recognizes the need to address effects of air pollutants on public welfare (e.g., crop damage, building damage, ecosystem health, and visibility), the cornerstone of air quality management in the U.S. is on the protection of human health. A focus on the health effects of air pollutants is particularly important in the early phases of air quality management programs when personnel and financial resources may be limited. The CAA requires the U.S. EPA to implement air quality standards to address those pollutants that are known to cause health effects and are relatively pervasive throughout the country. The U.S. EPA establishes two levels of air quality standards related to these pervasive pollutants: primary standards intended to protect human health; and secondary standards intended to protect general welfare.

The CAA also includes requirements for U.S. EPA to address specific air pollutants that are known or suspected to cause health effects but are more localized depending on the industrial source mix in any given area. These pollutants are known as hazardous air pollutants (HAPs). Currently, there are 188 compounds on the list of HAPs. The control of these pollutants is being addressed by the adoption of emissions standards based on the availability of control devices or measures applicable to individual source types (technology standards), rather than on air quality levels (health-based standards).

a. National Air Quality Data

The air quality trends discussed here relate mainly to human health concerns or primary standards for the six pollutants, summarized in Table II-1, that are subject to national air quality standards U.S. EPA, 2000a). The atmospheric concentration of these six criteria pollutants is measured at hundreds of air monitoring sites across the country. Table II-2 shows the percent change in air quality over the past two decades, using national averages for each of the pollutants. While these national trends are encouraging, the use of averages over many different locations with quite different conditions masks the extremes in air quality concentrations. A 2000U.S. EPA report notes that, “while the national trends continue to improve, air quality trends for some areas, including rural locations, have actually worsened (2000a).” Health effects and trends for key pollutants –particulate matter, sulfur dioxide, ozone, and nitrogen oxides – are discussed below.

Table II-1. Summary of Original and Current U.S. NAAQS

Pollutant	Original Standard	Current Standard	Standard Type
Carbon Monoxide (CO)			
8-hour Average	9 ppm	9 ppm	Primary
1-hour Average	35 ppm	35 ppm	
Nitrogen Dioxide (NO_2)	0.053 ppm	0.053 ppm	Primary & Secondary
Ozone (O_3)			
1-hour Average	0.08 ppm (1)	0.12 ppm (1979)	Primary & Secondary
8-hour Average	(2)	0.08 (1997)	
Lead (Pb)			
Quarterly Average	(2)	1.5 ug/m^3 (1978)	Primary & Secondary
Particulate (PM_{10})			
Annual Arithmetic Mean	75 ug/m^3(3)	50 ug/m^3 (1987)	Primary & Secondary
24-hour Average	260 ug/m^3(3)	150 ug/m^3 (1987)	
Particulate ($PM_{2.5}$)			
Annual Arithmetic Mean	(2)	15 ug/m^3 (1997)	Primary & Secondary
24-hour Average		65 ug/m^3 (1997)	
Sulfur Dioxide (SO_2)			
Annual Arithmetic Mean	0.03 ppm	0.03 ppm	Primary
24-hour Average	0.14 ppm	0.14 ppm	Primary
3-hour Average	0.50 ppm	0.50 ppm	Secondary

(1) The original standard was specified for total photochemical oxidant
(2) These standards were not promulgated until dates indicated
(3) The original standard was specified for total suspended particulate matter (TSP)

Particulate Matter

Particulate matter is linked to a number of significant health effects, and contributes to environmental effects like acid rain and problems with visibility. Particles can accumulate in the body and create respiratory problems and decreased lung function. Particles that are less than or equal to 10 micrometers in diameter (PM_{10}) are considered to pose a greater threat to human health than larger particles, due to their ability to pass deeply into the lungs. In recent years attention has focused on even finer particles as posing the greatest threat to human health.

Particulate matter is now measured in the U.S. as PM_{10} and $PM_{2.5}$. Table II-2 shows that there was an 19 percent decrease in national average concentrations between 1991 and 2000. There was a slight (1%) increase in PM_{10} concentration between 1998 and 1999, which was the first increase recorded since PM_{10} measurements began in 1988. This was likely due to the increased smoke from major wildfires throughout the west and in Florida in 1999, which was a particularly active year for forest wildfire. Ambient measurements of $PM_{2.5}$ began in 1999. Preliminary trends in $PM_{2.5}$ air quality indicate a slight downward trend, but with only three years of data available it is not possible to make conclusions about air quality trends for $PM_{2.5}$. The observed trend from 1999 through 2001, the last year of processed data, may be related more to weather and other external influences than changes in the sources of $PM_{2.5}$, and its precursors. Regionally, higher levels of $PM_{2.5}$ exist in regions of the Southeast, Mid-Atlantic and

Table II-2. Trends in National Air Quality Over Past Two Decades
(Source: http://www.epa.gov/airtrends/data/aq.html)

Percent Change in Air Quality		
	1981 - 2000	1991 - 2000
NO_2	-14	-11
O_3 1- hour 8- hour	-21 -12	-10 -7
SO_2	-50	-37
PM-10	-	-19
PM-2.5	No trend available	
CO	-61	-41
Pb	-93	-50

Mid-West (into the Ohio River Valley area) and also in central to southern California. U.S. EPA, 2001a).

Sulfur Dioxide

Sulfur dioxide (SO_2) is a respiratory irritant causing decreased lung function which can be severe in sensitive populations. Exposure to SO_2 alone or in combination with particulate matter also aggravates other respiratory conditions such as asthma and cardiovascular disorders. As shown in Table II-2, national average SO_2 concentrations decreased by 37 percent from 1991-2000. This steep rate of decline leveled off toward the end of the period, and from 1998 to 1999 SO_2 concentrations decreased by 3 percent. U.S. EPA, 2001a). In rural locations, the mean concentrations of SO_2 are lower than those in urban and suburban sites.

Ozone

Ozone is formed through reactions in the atmosphere involving VOCs, NO_x and sunlight. Ozone is measured in short term (1-hour) and prolonged (8-hour) exposures. As seen in Table II-2, the short-term concentration of ozone decreased by 10 percent from 1999-2000 while the decrease in exposure relative to the longer-term average was less dramatic at 7 percent. Regionally, the results are mixed, where the Mid-Atlantic, Southeast, Midwest, and North-Central regions of the U.S. have actually experienced an increase in ozone concentrations. These increases have been attributed to weather conditions that are more conducive to O_3 formation U.S. EPA, 2001a).

In urban areas, there was steady improvement in ozone levels up until 1994, when progress slowed. Ozone levels were also improving in rural areas through the 1980s, but then concentrations actually increased by 2 percent between 1990 and 1999 U.S. EPA, 2001a).

Nitrogen Dioxide

Oxides of nitrogen (NO_x) refers to the sum of nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x is emitted from all combustion sources. The distribution of NO and NO_2 emitted directly from any source is dependent on the operating characteristics of the specific combustion source. Once NO_x is emitted, normal atmospheric chemistry associated with oxidation processes causes the nitrogen to shift back and forth from NO to NO_2. Some specific sources emit larger fractions of NO_2 from the source but the primary exposure concern related to NO_2 is the concentration of NO_2 in urban areas during the typical oxidation processes, such as those associated with ozone formation chemistry. The primary health concern related to NO_2 is associated with difficulties in pulmonary function and respiratory illness. For long-term exposure, NO_2 is thought to increase respiratory infection and potentially damage the lungs structurally. As seen in Table II-2, there was a 11% decrease in NO_2 during 1991-2000. All areas in the U.S. that once exceeded the national standard for NO_2 are now in compliance U.S. EPA, 2001a).

Carbon Monoxide and Lead

Carbon monoxide (CO) is emitted from incomplete combustion processes. The dominant source of CO in the United States is from internal combustion engines used primarily in mobile sources, which represented approximately 82% of the national total CO emissions in the United States in 2001. Carbon monoxide interferes with the exchange of oxygen to the blood in the lungs, and can cause dizziness, disorientation, vomiting, and, after prolonged exposure to high concentrations, death. Increasingly stringent motor vehicle exhaust emissions standards have steadily decreased CO concentrations over the past several decades. Carbon monoxide emissions have been reduced nationwide by 41% between 1990 and 2000. Most areas in the United States are currently in compliance with the CO air quality standard, and continued emissions reductions from mobile source control programs are sufficient to keep areas in compliance with the standard for the immediate future.

Lead is a heavy metal that causes neurological damage in humans and is particularly dangerous for children who are exposed repeatedly to high lead levels during the development of the nervous system. It can result in decreased mental development. The principal source of air borne lead in the United States in the 1970s was from the combustion of leaded gasoline. The U.S. phased out leaded gasoline and the sale of leaded gasoline is now entirely prohibited in the U.S. The use of unleaded gasoline drastically reduced the concentrations of lead in the atmosphere, and the only remaining areas of concern for lead air pollution are regions immediately surrounding lead smelters, lead-acid battery manufacturing facilities, and other selected processes. Overall lead concentrations have been reduced by 97% since the 1970s as a direct result of the use of unleaded gasoline.

Air Quality Index

The air quality index (AQI) is a method to help the general public assess pollution levels with regard to health effects U.S. EPA, 2001a). The AQI represents observed pollutant concentrations in terms of the six color-coded categories shown in Table II-3. An AQI value of 100 generally corresponds to the national air quality health standard for the pollutant. So, AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy—at first for certain sensitive groups of people, then for everyone as AQI values get higher. The color codes are used to simplify the communication of the air quality threat to the public. For example, parents with asthmatic children know that on a code orange day they should limit the amount of time their children are allowed to take part in strenuous outdoor exercise. Similarly, people with respiratory disease should be careful about their outdoor activities on any code red day.

Table II-3. Air Quality Index Categories

Air Quality Index Values	Levels of Health Concern	Color Code
0-50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

In large metropolitan areas (more than 350,000 people), state and local agencies are required to report the AQI to the public daily through public broadcasts and newspapers. When the AQI is above 100, they must also report which groups (e.g. children, people with asthma or heart disease) may be sensitive to the specific pollutant. If two or more pollutants have AQI values above 100 on a given day, agencies will report all the groups that are sensitive to those pollutants. Although it is not required, many smaller communities also report the AQI as a public health service.

Many metropolitan areas also report an AQI forecast that allows local residents to plan their activities to protect their health. They may provide suggestions about how to protect your health when the air is unhealthy to breathe. The AQI is a national index, so the values and colors used show local air quality and the associated level of health concern will be the same everywhere in the U.S. The AQI is reported in newspapers, on television and radio, on the Internet, and on state and local telephone hotlines. The following is an example report: *Tomorrow, the AQI for Center City is predicted to be between 160 and 170, a code red day. This means that air pollution will be at unhealthy levels. The combination of cold winter air and morning rush-hour traffic will cause carbon monoxide to rise to unhealthy levels. People with heart disease should plan to limit moderate exertion and avoid sources of carbon monoxide, such as heavy traffic.*

Table II-4 lists eight representative, major metropolitan areas in the U.S. and the corresponding number of days per year with AQI values greater than 100 during the period 1990-1999. The table indicates varying trends for different U.S. cities. For example, Table II-4 shows that the air quality in the Los Angeles and Long Beach, California region appears to have made significant improvements since the early 1990s (i.e., a significant reduction in the number of days per year with the AQI over 100). Baltimore, MD, on the other hand, shows no obvious trend over the 1990-1999 period.

Hazardous Air Pollutants

Hazardous air pollutants (HAPs), also known as air toxics, are chemicals that are known to cause human health effects but are not observed in all areas. Generally, exposure to these pollutants is confined to populations that are located near selected sources. Residents in areas immediately downwind of such a concentration of sources might be exposed to those particular HAPs that are associated with those sources, while populations in other cities or even in other parts of the same city may not be exposed to the same HAPs. Therefore, it is inefficient to attempt to regulate these types of pollutants on a national scale using the ambient air quality standard model. The CAA, however, requires that U.S. EPA address all air quality issues that cause health effects. Originally, the CAA required U.S. EPA to implement programs to reduce

Table II-4. Number of Days with AQI >100 (U.S. EPA, 2001a)

Metropolitan Statistical Area	# Trend Sites	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Altanta, GA	10	42	23	20	36	15	35	25	31	50	61
Baltimore, MD	17	29	50	23	48	41	36	28	30	51	40
Houston, TX	23	51	36	32	28	38	66	26	47	38	50
Los Angeles - Long Beach, CA	38	173	168	175	134	139	113	94	60	56	27
New York, NY	29	36	49	10	19	21	19	15	23	17	24
Philadelphia, PA-NJ	36	39	49	24	51	26	30	22	32	37	32
Riverside-San Bernardino, CA	36	159	154	174	168	149	124	119	105	95	93
San Diego, CA	23	96	67	66	58	46	48	31	14	33	16

the concentrations of these HAPs to levels that would protect the public health with an ample margin of safety. Clinical evidence suggests that there is no level of exposure that will absolutely guarantee the absence of any health effect for many of these pollutants. Therefore, the language associated with protection with an ample margin of safety, resulted in many legal challenges and as a result few emission standards were established for the HAP pollutants.

In the 1990 CAA amendments, Congress shifted the emphasis from a control program based on the risk associated with exposure to these pollutants to one based on the available technology that could be applied to control emissions of these pollutants. This shift resulted in a 10-year effort to define and implement standards to control air emissions of the HAPs based on the maximum achievable control technology (MACT) for specific sources of HAP emissions. Only after the full implementation of the technology standards was realized would the agency return to the issue of exposure risk associated with these pollutants. U.S. EPA estimates that the full implementation of the MACT emissions standards will reduce HAP emissions by 75% to 90% for most source categories and will collectively reduce emissions of HAPs by approximately 1.5 million tons.

The ambient measurements of these air quality parameters are used to define the severity and geographic scope of the air pollutants to help estimate the health effects issues that must be addressed under the CAA. Ambient monitoring data is, therefore, a critical component of the goal setting process, and in tracking the successes of both the regulatory and voluntary programs designed to make progress toward those goals.

b. National Emissions

A comprehensive emissions inventory is prepared at the source category level on a three-year cycle. While measurement is always the preferred method for calculating emissions, most of the emissions information is estimated by the use of an emission factor or through mass balance type approaches. The national emissions inventory is prepared to a large extent by state and local agencies and those inventories are submitted to the U.S. EPA. U.S. EPA adds emissions estimates for missing source categories and estimates for areas that are not covered by the state inventories to assemble the complete inventory. The national inventory includes emissions estimates for all of the important air quality pollutants resulting from stationary point sources, area sources, highway mobile sources, non-road mobile sources, and biogenic/natural sources.

Emissions inventories represent an important component of the air quality management system. Emissions estimates help decision makers identify the primary source categories responsible for any particular air quality problem. Developing emissions inventories over time provides a record of changes in emissions levels that can be associated with changes in observed air quality to track the effectiveness of different control strategies. The emissions magnitude has been reduced significantly for most sources on a per unit activity basis over the years. There have been significant increases in the amount of activity associated with many of the source categories, however, so the trends in overall national emissions are not as dramatic. As seen in Table II-5, emissions nationwide have decreased over the past decade for all of the principal pollutants except $PM_{2.5}$. The record for $PM_{2.5}$ emissions is not as long as for the other pollutants, and there are significant natural sources of $PM_{2.5}$, including wildfire, and wind blown dust that are not subject to national or state control programs, so it is difficult at this early stage to make conclusions about $PM_{2.5}$ control strategy effectiveness. Pollution controls mandated under the Clean Air Act Amendments thus appear to have made a substantial contribution to air quality, especially considering that most emissions improvements occurred despite the increase in economic activity and population over this same period.

Table II-5. National Emissions Trends for the United States (Source, http://www.epa.gov/ttn/chief/trends/index.html)

	Percent Change in Emissions	
	1980-2001	1999-2001
Carbon monoxide	-35	-18
Oxides of nitrogen	-17	-11
Volatile organic compounds	-42	-24
PM-10		-11
PM-2.5		1
Sulfur Dioxide	-39	-28

Although this decrease in emissions is encouraging, there were still greater than 200 million tons of air pollutants released into the atmosphere in the U.S. in 2001 (http://www.epa.gov/ttn/chief/trends/trends01/trends2001.pdf). The emission trends for these pollutants in the United States are shown in Figure II-1 from 1900-1998. Data for years prior to 1970 are estimated by applying ratios and other assumptions relative to economic activity and population for those years.

Volatile Organic Compounds

As mentioned in the previous sections, VOCs are one of the key components that contribute to the formation of ozone. They are emitted from a wide variety of sources, a large part of which are biogenic or natural. The main man-made sources of VOCs are transportation (47%) and industrial processes (44%) of which solvents are a major component, which includes the manufacture, distribution and storage of organic liquids. Emissions of man-made VOCs were reduced by 24 percent over the 1991-2001 period, as shown on Table II-5 U.S. EPA, 2001a). Figure II-2 shows the distribution of man-made VOC emissions by source category.

Figure II-1. U.S. National Emission Trends for Pollutants from 1900-1998 for NOx, VOC, SO2, and PM10 (U.S. EPA, 2001b)

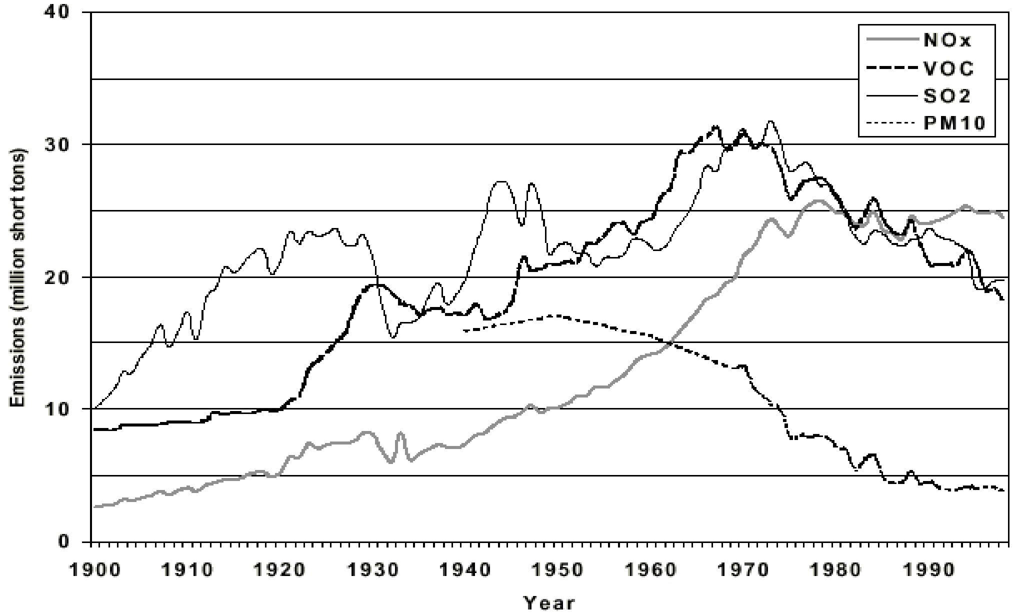
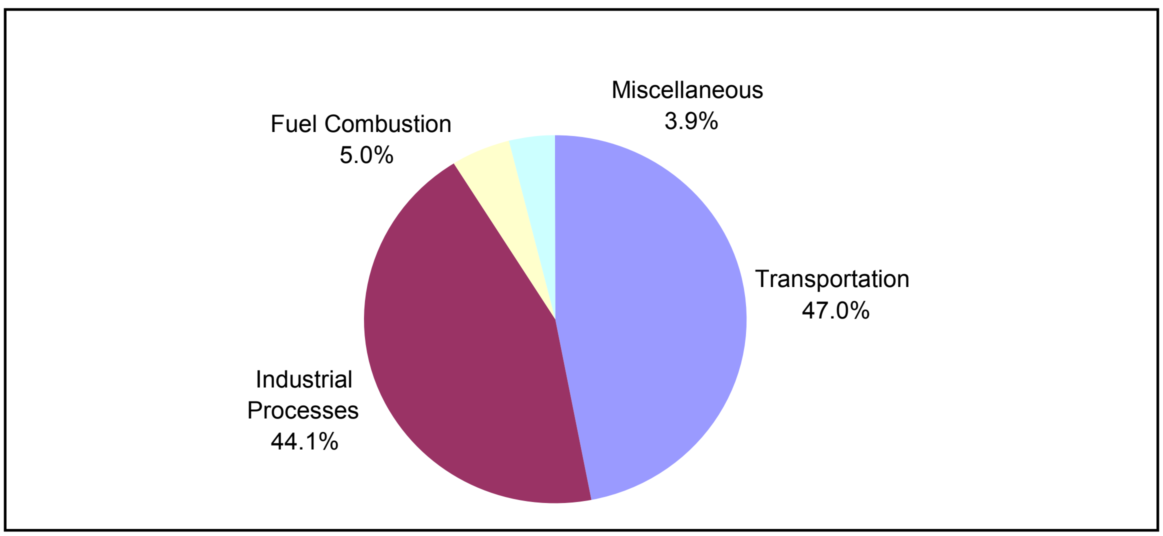


Figure II-2. VOC Emissions by Source



Particulate Matter

$PM_{2.5}$ can be created from traditionally measured sources such as fuel combustion (i.e. motor vehicles, residential fireplaces and wood stoves, power generation and industrial process), but it can also be formed in the atmosphere from gases that include SO_2, NO_x and VOCs. $PM_{2.5}$ emissions in the United States include the mass of these fine particles that are emitted directly by the source, while ambient concentration measurements include both the directly emitted mass and the secondary mass that is formed in the atmosphere through gas to particle conversion processes. PM_{10}, or coarse particles, can result from vehicles, wind blown dust, or crushing and grinding operations. Traditional man-made sources, such as transportation, industrial processes and fuel combustion, account for about 7 and 21 percent of the source for coarse and fine particulate matter, respectively; therefore, combustion sources are a greater contributor of $PM_{2.5}$ than PM_{10}. Miscellaneous sources (such as wildfires) account for approximately 47 and 40 percent, and fugitive dust for 33 and 23 percent for $PM_{2.5}$ and PM_{10} sources, respectively. Figures II-3 and II-4 show the distribution by source category of $PM_{2.5}$ than PM_{10} emissions respectively.

Figure II-3. PM 2.5 Emissions by Source Category

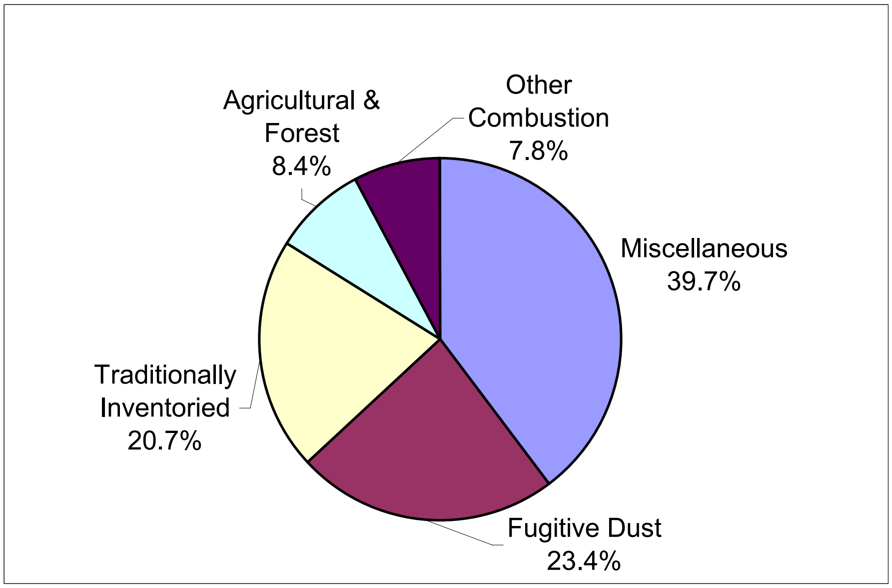
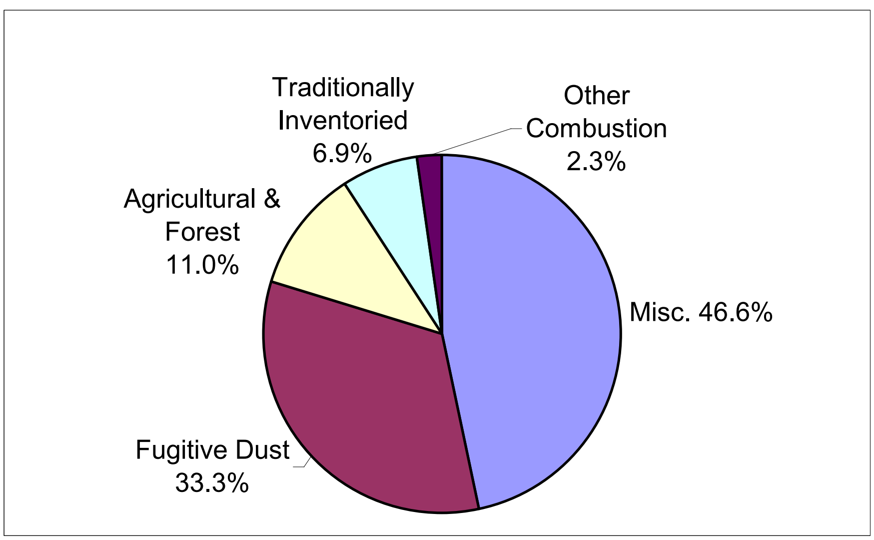


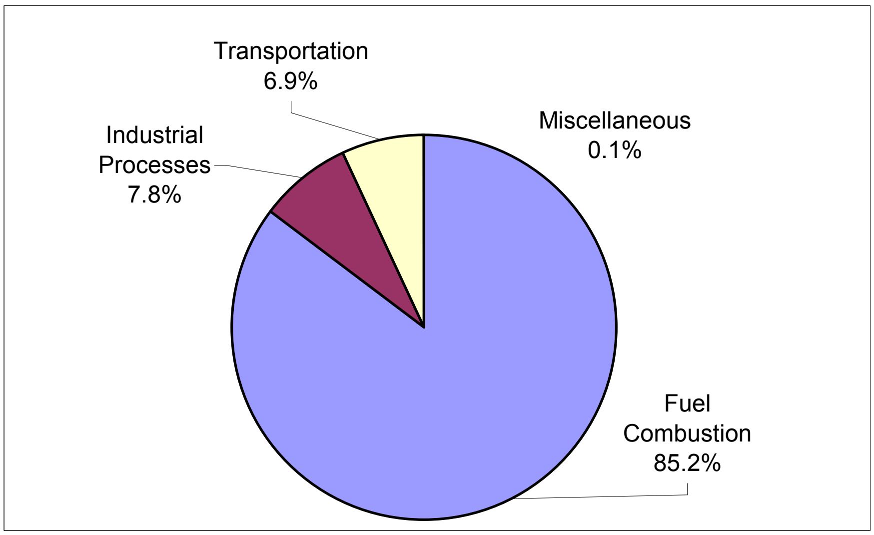
Figure II-4. PM_{10} Emissions by Source Category



Sulfur Dioxide

High concentrations of sulfur dioxide are usually measured near large industrial facilities, particularly those that burn sulfur-containing fuel (coal and oil) and conduct metal smelting. The major source of SO_2 is from fuel combustion, accounting for 85 percent of emissions. A 29 percent reduction was measured for SO_2 emissions during the 1991-2001 period, a significant portion of which is due to controls implemented by U.S. EPA under the Acid Rain Program that began in 1995 U.S. EPA, 2000a; U.S. EPA, 2001a). Figure II-5 shows the distribution by source category of SO_2 emissions.

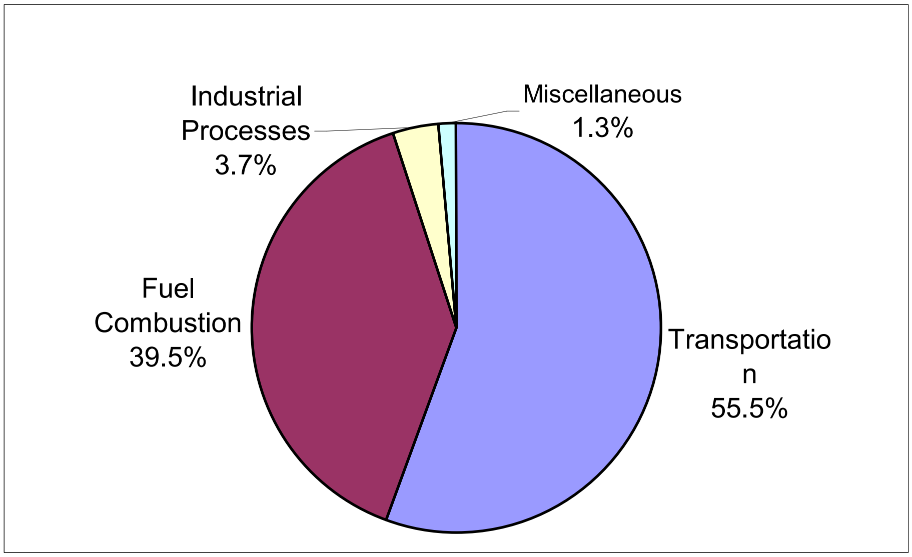
Figure II-5. SO_2 Emissions by Source Category



Nitrogen Oxides

Along with VOCs, nitrogen oxides are a major contributor to ozone formation in the atmosphere. Emissions of nitrogen oxides decreased 11 percent from 1991–2001, although approximately 8 percent of that change has occurred since 1998. Much of the reductions have been from electric generating units and highway mobile sources, while NO_x emissions from non-road mobile sources, and many industrial and waste disposal processes have been increasing steadily over that same time period. The role of NO_x in atmospheric chemical processes is very complex and it is difficult to draw conclusions from trends in NO_x emissions and ambient concentrations alone. It is likely that the available NO_x is taken up by competing chemical processes as the other precursors involved in ozone formation decline. Understanding these complex competing mechanisms is a difficult task that requires the application of sophisticated modeling approaches that are discussed later in this section. Mobile sources account for more than half of the national total NO_x emissions. Another 40 percent of NO_x is attributed to fuel combustion sources. Emissions reductions from large fuel combustion sources associated with the Acid Rain Program have helped to somewhat offset the increases in NO_x emissions from transportation sources. U.S. EPA, 2000a; U.S. EPA, 2001a). Figure II-6 shows the distribution by source category of NO_x emissions.

Figure II-6. NO_x Emissions by Source



Hazardous Air Pollutants

Historically, U.S. EPA has not developed national emissions inventories for HAPs. There is a significant effort underway, currently, to develop the tools and approaches required to prepare a comprehensive national level inventory of these pollutants and to update that inventory on a regular three-year schedule. This effort is needed to monitor the effectiveness of the HAP emissions source control regulations and to support further analysis of the risks associated with HAP releases. U.S. EPA is coordinating with state agencies and other stakeholders to facilitate the development of this national inventory. Although the process has not yet been completed, preliminary inventories have been developed and are publicly available at http://www.epa.gov/ttn/chief/net/1999inventory.html#final3haps. U.S. EPA, 2003a)

There is insufficient data available to support the development of any trends assessments related to HAP emissions. The most recent completed inventory that has been reviewed and documented was for 1996. The national total HAP emissions in that inventory are 4.63 million tons. Approximately half of that total is attributed to mobile sources and the remainder is split between point and area sources. Approximately 70% of the total HAP emissions are from sources in urban areas.

2. Laws and Regulations

The Clean Air Act (CAA) Amendments of 1970 serve as the principal source of statutory authority for controlling air pollution and establish the basic United States program for controlling air pollution. The CAA Amendments require U.S. EPA to set National Ambient Air Quality Standards (NAAQS) for certain pollutants (criteria pollutants); to develop programs to address specific air quality problems; establish U.S. EPA enforcement authority; and provides for air quality research. These amendments placed the major responsibility for achieving NAAQS by 1975 on the states via their implementation plans. To support the States Implementation Plans (SIPs) the CAA requires the U.S. EPA to provide technical assistance. In one support program, U.S. EPA establishes Control Techniques Guidelines (CTGs) for controlling air pollutants for specific industries. For stationary sources, the act requires U.S. EPA to establish New Source

Performance Standards (NSPS) for all major categories of polluting facilities. To regulate toxic or hazardous air pollutants the act provides the National Emissions Standards for Hazardous Air Pollutants (NESHAPs). The act also established the Federal Motor Vehicle Emission Standards. The principal result of implementation of the 1970 CAA Amendments was the establishment of the basic air quality management system and organization in this country.

The Clean Air Act of 1970 was amended in 1977. The 1977 Clean Air Act Amendments added the "Prevention of Significant Deterioration" (PSD) and "Nonattainment Provisions" to the Act. These Provisions established the New Source Review (NSR) program for construction and modification of new major sources. For those areas that have not attained NAAQS, the 1977 CAA Amendments provided a much longer and realistic time frame for states to achieve compliance with the NAAQS.

In 1990, Congress once again amended the Clean Air Act. The passage of the 1990 amendments marked an overall change in the federal approach to air pollution. The new legislation placed renewed emphasis on controlling emissions of hazardous air pollutants and introduced efforts aimed at controlling acid rain and ozone depletion in the atmosphere. Five major goals for protecting and promoting human health and public welfare are identified in the CAA as amended (Air Quality Management in the United States, Report of The National Research Council, 2004):

- Mitigating potentially harmful human and ecosystem exposure to six criteria pollutants;
- Limiting the sources of and risks from exposure to hazardous air pollutants, which are also called air toxics;
- Protecting and improving visibility impairment in wilderness areas and national parks;
- Reducing the emissions of species that cause acid rain, specifically SO_2 and NO_x;
- Curbing the use of chemicals that have the potential to deplete the stratospheric ozone layer.

Summaries of key the provisions from the CAA as amended in 1990 that pertain to this assessment project are presented below.

Title I – National Ambient Air Quality Standards

To counter the failure of a large number of urban areas to meet the NAAQS for ozone and carbon monoxide, Congress placed deadlines for attaining compliance with the air quality standards on cities classified according to a five-level scheme ranging from "marginal" (three years) to "extreme" (20 years). The classification depends upon the geographic location, severity of the nonattainment problem, and the particular mix of sources present at each location. The definition of a "major source" for the ozone precursor (VOC) was placed on a sliding scale so that states could regulate businesses releasing even small levels of volatile organic compounds (VOCs) in the most severe areas. New requirements were imposed on stationary sources, motor vehicle refueling, inspection and maintenance and the use of consumer and commercial products. Congress placed increased emphasis on control and compliance with the use of economic incentives such as increased fees and marketable permits. Depending upon the severity of the nonattainment area, states are required to reduce the amount of VOCs released within their borders every year, establish a clean-fuel program, require employers to increase passenger occupancy per vehicle, apply reasonable available control technology (RACT) to all major sources of emissions, and comply with new source review requirements, permit requirements for most stationary sources, more stringent emission offset requirements for new or modified sources, and additional refueling controls. In addition, some states are required to adopt these measures simply by virtue of the state's location within the Ozone Transport Region, which was created by statute for the region between the District of Columbia and Maine because of the long-range transport of ozone and its precursors.

For carbon monoxide nonattainment areas, the Act required the implementation of enhanced vehicle inspection maintenance programs, transportation control measures and the use of oxygenated fuels. For PM_{10} nonattainment areas, implementation of RACT measures or best available control (BACT) measures were required depending upon the severity. Major sources were defined as those emitting 70 tons or more each year.

In all cases (ozone, CO and PM_{10}), a demonstration using air quality modeling that the plan will provide for attainment on schedule was required. Areas failing to meet the attainment date (through ambient air quality monitoring) will be reclassified, by operation of law, to the next higher level nonattainment status.

Title II – Mobile Sources

The motor vehicle provisions of the Act required an additional reduction in hydrocarbon and nitrogen oxide emissions for model year 1995 and for light-duty autos in later years. New PM urban bus standards were set forth for model year 1994 also requiring greater reductions. Evaporative vapor recovery systems were required for all light-duty autos by 1995. Auto warranty periods on major emission control components were extended to 8 years or 80,000 miles after 1995. Requirements were set forth for the use of reformulated gasoline in the most severe nonattainment areas beginning in 1995. Authority was extended to regulate fuels for nonroad engines. Diesel fuel sulfur content was set not to exceed 0.05% by weight to reduce PM emissions. The Act mandated the phase out by 1995 of the use of any fuel that contains lead or lead additives and established procedures for the introduction of clean-fuel fleet programs for the most serious nonattainment areas. Requirements were expanded for increased record keeping and penalties increased for tampering with vehicle emission controls.

Title III – Hazardous Air Pollutants

The 1990 amendments established a list of 189 chemicals and metal compounds to be regulated as air toxics. Congress directed U.S. EPA to identify categories and subcategories of both major and area sources which emit the list pollutants. U.S. EPA is to develop two types of emission standards applicable to these facilities. First, a technology-based standard and second a health-based standard. The technology based standard will require major stationary sources to meet emission limitations reflecting the use of maximum achievable control technology (MACT). Area sources may be subject to a MACT standard or a more general achievable control technology standard. In the second round of regulation U.S. EPA is to evaluate the health risks after implementing the technological controls. Sources subject to this regulation will need to obtain a permit.

Congress also directed the establishment of a major new program aimed at preventing or mitigating release of extremely hazardous air pollutants from accidental release. Emission sources handling levels above a threshold amount are required to undertake risk assessments, prepare emergency plans, and take steps as necessary to prevent release or to minimize its consequences.

Title IV – Acid Deposition (or Acid Rain)

To alleviate the problem of acid rain, Congress coupled stronger limitations on the emissions of SO_2 and NO_x with a new system of emission privileges. The program established a plan for reducing overall emissions of SO_2 and NO_x to less than the emission levels in 1980. For each of the 111 major fossil-fired steam generating sources, emission limitations on sulfur dioxide pollution is enforced by a complex system of pollution "allowances" based on present emissions, with each allowance equal to one ton of sulfur dioxide per year. The allowances are fully transferable and marketable and may be bought and sold for cash. An auction system was set up in the statute, which is the marketplace for both government and private party sales of allowances. SO_2 allowances were allocated in two phases. In Phase 1, which lasted from 1995 through 1999, only the 111 major utilities were subject to control. In Phase II, which began in 2000, all electric utility steam generating units received allowance allocations which they may not exceed, but can trade or sell for cash. Additional incentives were also granted for coal plants that drastically reduced emission levels. To reduce NO_x emissions, the statute requires emission limitations be placed on coal-fired utility boilers based on the type of burner technology used.

Title V – Stationary Source Operating Permits

This new provision required that any source emitting an air pollutant regulated under the Clean Air Act will have to obtain an operating permit. Prior to this program, each individual air pollutant source was not required to obtain a permit. This scheme will require nearly all stationary sources of air emissions to obtain individual operating permits.

The permit program includes both enforceable emissions limitations and compliance schedules. The statute required U.S. EPA to develop permitting regulations for state programs which impose state authority to issue permits, public notification requirements, monitoring and reporting requirements and permit fees. The states were then required to develop the permit programs with assistance and approval from U.S. EPA.

Title VI – Stratospheric Ozone and Global Climate Protection

This enabling law provides for the phase-out of the U.S. production and use of chloroflurocarbons (CFC's) and hydrochloroflurocarbons (HCFC's) in accordance with the Montreal Protocol. These are the major compounds associated with the destruction of the stratospheric ozone. The process calls for U.S. EPA to require manufacturers, importers and exporters file quarterly reports and reduce production and consumption over time with nearly the complete phase of CFC's by 2000 and HCFC's by 2030. The act gives authority to U.S. EPA to require product labeling for CFC and HCFC containing products. The act authorizes U.S. EPA to develop mandatory standards regarding the use and disposal of CFC's and HCFC's during the service and repair, disposal of appliances and industrial process of refrigeration.

Title VII – Provisions Regarding Enforcement

Finally, the Clean Air Act Amendments gave U.S. EPA broad new authorities to enforce all of the new programs in the law. These authorities also increased the range of enforcement options available for all types of violations. Substantial criminal fines and penalties are authorized for violations which include: negligent or knowing violations which result in endangerment of others, knowing violations of State Implementation Plans which occur after the violator is on notice of violation, knowing violations of certain permit provisions, knowing violations of the acid rain and stratospheric ozone protection provisions, and knowingly filing a false statement or for omissions in record-keeping, monitoring, or reporting.

Criminal violations of the CAA were upgraded from misdemeanors to felonies. Also included were provisions for administrative penalties, field citations, and rewards of up to $10,000 to persons who provide information leading to a criminal conviction or civil penalty.

Implementation of the CAA

The CAA prescribes a set of responsibilities and relationships among federal, state, tribal and local agencies in order to achieve air pollution control. U.S. EPA and the states are jointly charged with protecting the nation's environment. To meet this challenge, U.S. EPA and the states are striving to build the kind of open, productive relationship that will facilitate effective, joint management of the nation's environmental agenda.

Laws often do not include all the details. In order to make the laws work on a day-to-day level, Congress authorizes certain government agencies -- including U.S. EPA -- to create regulations. Regulations set specific rules about what is legal and what isn't. For example, a regulation issued by U.S. EPA to implement the Clean Air Act might state what levels of a pollutant -- such as sulfur dioxide -- are safe. It would tell industries how much sulfur dioxide they can legally emit into the air, and what the penalty will be if they emit too much. Once the regulation is in effect, U.S. EPA then works to help people comply with the law and to enforce it. More details about air related regulations can be found at http://www.epa.gov/regulation.

The federal government's role is coordinated by U.S. EPA and is intended in part to provide a degree of national uniformity in air quality standards and approaches to pollution mitigation so that all individuals are assured a basic level of environmental protection. State and local governments are given much of the responsibility for implementing and enforcing the federal mandated rules and regulations within their jurisdictional domains, including developing and implementing specific strategies and control measures to meet national air quality standards and goals. Most federal environmental statutes embrace the concept that states should have primary responsibility for operating regulatory and enforcement programs. Today most states carry out basic regulatory and enforcement functions of traditional environmental programs as well as innovative new approaches to address particular state and local needs.

For more detailed information including the full text of the CAA and the 1990 amendments visit http://www.epa.gov/oar/caa/. A plain language guide to the act can be found at http://www.epa.gov/oar/oaqps/peg_caa/pegcaa11.html. A more detailed explanation of the evolution of the CAA is included in Section II.5 of this report.

3. U.S. AQM System

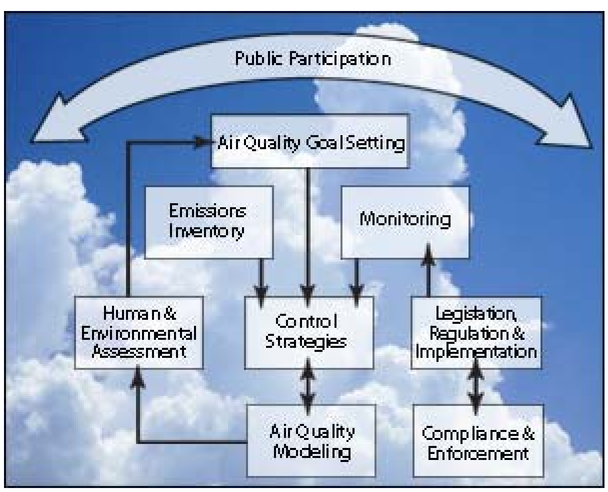
The air quality management process in the U.S. involves a series of steps, as mentioned in previous sections. These are as follows:

- Air quality goal setting;
- Emissions inventory;

- Monitoring;
- Air quality modeling;
- Control strategies;
- Human and environmental assessment;
- Compliance and enforcement;
- Evaluation of effectiveness and modification of controls as necessary; and
- Public Participation.

In the United States air quality goals are primarily set to improve public health although some programs are implemented to address public welfare issues caused by air pollutants. Ambient monitoring data and emissions inventories serve as the basis for identifying the specific problems that can be addressed through air pollution mitigation efforts. The establishment of air quality management controls is a complex process involving the federal and state governments, as well as representatives of industry, citizens, local air quality control boards, regional air quality control boards, and others. Much of the early efforts to develop control strategies in the United States have been based on a "command and control" regulatory approach. The states, however, are primarily responsible for the basic planning for and implementation of most air quality management programs in the U.S. The overall process of air quality management is depicted graphically in Figure II-7. The AQM System Flow Chart shows the most basic relationships between these activities, but this is for illustrative purposes only. In reality, each box would have lines connecting to and from each additional box on the chart. It is also important to recognize that the entire AQM process is dynamic - there is a continuous review and assessment of standards and strategies based on their effectiveness and new research on health and environmental effects. The following subsections provide an overview of each step in the process.

Figure II-7. Flow Chart Representing the Basic Air Quality Management Process



a. Air Quality Goal Setting

Air quality goal setting is the process by which a country sets targets for its air quality management system. These goals may represent an acceptable level of a pollutant in the ambient air, or a desired level of control for a facility that emits pollutants. For most countries, this represents the starting point for any air quality management program.

The United States controls air pollutants through two main programs: (1) the National Ambient Air Quality Standards (NAAQS) program, and (2) the Hazardous Air Pollutants (HAP) program.

NAAQS are established for six pollutants: ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, and particulate matter. The standards are required by general national legislation to protect public health; the specific levels are set by regulations or rules developed by the U.S. Environmental Protection Agency U.S. EPA).

HAPs are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. In the United States, goal setting for air toxics is a two-staged process:

- First stage - U.S. EPA sets technology-based national emission standards to address air toxic pollution. These standards require major stationary sources to meet emission limitations by using maximum achievable control technology; and
- Second stage - U.S. EPA is then required to evaluate the health risks that may remain after the technological controls have been implemented. Some sources may be subject to additional control requirements if they pose an unacceptable health risk to populations living near the facility.

A good synopsis to help understand the air quality goal setting process in the U.S. is described in the Citizens' Guide to Air Quality in Montana (Montana Department of Environmental Quality, 2004), which provides a basic description of the federal and Montana state ambient air quality standards, regional ambient air quality concerns, and case histories for four areas in Montana that highlight the success of their state implementation plans. For more information visit http://www.epa.gov/air/aqmportal.

b. Emissions Inventory

The development of a complete emission inventory is an important step in an air quality management process. Emission inventories are used to help determine significant sources of air pollutants, establish emission trends over time, target regulatory actions, and estimate air quality through computer dispersion modeling. An emission inventory includes estimates of the emissions from various pollution sources in a specific geographical area. A complete inventory typically contains all regulated pollutants.

Different methods for calculating the emissions inventories are available, and the choice of method depends on the availability of data, time, staff and funding. The methods may include, but are not limited to: continuous monitoring to measure actual emissions; extrapolating the results from short-term source emissions tests; and combining published emission factors with known activity levels.

An emission factor may be used to estimate emissions when actual emission data is not available. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category. General emission factors are available to the public, and may be accessed under the AP-42 link below. However, variations in the conditions at a given facility, such as the raw materials used, temperature of combustion, and emission controls, can significantly effect the emissions at an individual location. Whenever possible, the development of local emission factors is highly desirable. For more information visit http://www.epa.gov/air/aqmportal.

c. Monitoring

Air quality monitoring is carried out to assess the extent of pollution, ensure compliance with national legislation, evaluate control options, and provide data for air quality modeling. There are a number of different methods to measure any given pollutant, varying in complexity, reliability, and detail of data. These range from simple passive sampling techniques to highly sophisticated remote sensing devices. A monitoring strategy should carefully examine the options to determine which methodology is most appropriate, taking into account initial investment costs, operating costs, reliability of systems, and ease of operation.

The locations for monitoring stations depend on the purpose of the monitoring. Most monitoring networks are designed with human health objectives in mind, and monitoring stations are therefore established in population centers. Many governments (local, regional or national) give specific guidelines on where to monitor within these areas - next to busy roads, in city center locations, or at a location of particular concern (e.g., a school, hospital). Background monitoring stations are also established, to act as a "control" when determining source apportionment.

Emissions Measurement is the science of characterizing and measuring air pollutant emissions. The measurement of both type and quantity of these contaminants is an important part of obtaining the data needed to implement a meaningful control program. The process of monitoring particulate and gaseous emissions from a stationary source is often referred to as source sampling or source testing.

Once data are collected from a monitoring system, they must be stored in data management systems and databases. Subsequently, the data must be retrieved and analyzed to see what they reveal about the effectiveness of regulatory standards, the accuracy of modeling, impacts on health endpoints, and as an overall way of assessing. In the U.S. these data are collected and housed in the Air Quality Subsytem (AQS). The AQS contains ambient air pollution data collected by U.S. EPA, state, local, and tribal air pollution control agencies from thousands of monitoring stations. AQS also contains meteorological data, descriptive information about each monitoring station (including its geographic location and its operator), and data quality assurance/quality control information. For more information visit http://www.epa.gov/air/aqmportal.

d. Air Quality Modeling

Air Quality modeling is the mathematical prediction of ambient concentrations of air pollution, based on measured inputs. Modeling is the necessary substitute for ubiquitous air quality monitoring, which is impossible. Air quality managers can use models to predict the impacts from a potential emitter, which is useful for permitting new sources. Managers can also apply models for the simulation of ambient pollution concentrations under different policy options, as a tool to both make and justify a decision. Finally, models can be used to determine the relative contributions from different sources as a tool for tracking trends, monitoring compliance, and making policy decisions.

Modeling for air quality management purposes typically falls into two broad categories: dispersion modeling and receptor-based modeling. Briefly, dispersion models are used to predict ambient concentrations and receptor (or source apportionment) models use ambient data to determine the sources. They can be differentiated a few ways: on the required model inputs (i.e., meteorological data); on the spatial scale (global; regional-to-continental; local-to-regional; local); on the temporal scale (episodic models, long-term models); on the treatment of the transport equations (Eulerian, Lagrangian models); on the treatment of various processes (chemistry, wet and dry deposition); and on the complexity of the approach. The choice of model depends on a combination of the available data and the needs of the researcher.

The evolution of air quality modeling in the U.S. has been a lengthy process stretching over the past nearly three decades. Modeling capabilities have been developed in response to the developing understanding of air pollutant issues and of the measures required to manage these issues. As these factors advanced, the analytical requirements for air quality management also became more complex, and models were developed as tools to meet these requirements. The availability of increasingly comprehensive data related to air quality also supported the development of more complex models (Jang and Chang).

First-generation modeling systems focused on single pollutants, and estimated downwind ambient concentrations based on physical transport algorithms, These were Lagrangian trajectory models (Gaussian dispersion models, Lagrangian box models), and were designed to assess the effects of individual air pollutants from individual or a small number of sources on downwind air quality (ibid). They were used largely for impact assessments and development of control strategies for primary pollutants.

The recognition of the importance of atmospheric photochemistry and of secondary pollutants formed in the atmosphere, and the increasing understanding of the regional nature of air quality issues, led to the development of a second generation of air quality models. These regional and urban air quality models, including the ROM, RADM, and UAM models, are 3-dimensional Eulerian grid models with sophisticated photochemistry simulation mechanisms capable of simulating the chemistry of ozone SOx, NOx, and (in the case of RADM) acid formation and deposition. These models were specifically designed to simulate ozone concentrations on the urban or regional scale. UAM is widely used in metropolitan areas for ozone attainment demonstration and the assessment of the effects of control strategies.

Subsequent to the development of the second-generation models it became apparent that the environmental regulatory community needed models to provide a variety of functions to support analysis and decision-making. It was also recognized that the atmospheric transformations and formations of many air pollutants are closely linked, and that therefore the development of effective control strategies requires models that are capable of simulating multiple pollutants simultaneously. More than eight years ago EPA embarked on a major effort to develop a third-generation air quality modeling system that would take advantage of advanced computer hardware and software technologies to simulate the behavior of numerous pollutants in a single area or atmosphere, accounting for the atmosphere interaction, formation, and transformation of these multiple pollutants; and simulating the gate of all of these pollutants simultaneously.

The resulting "one atmosphere" modeling system, the Models-3 Community Multiscale Air Quality (CMAQ) modeling system, was released in 1998. This modeling system provides important analytical capability for the U.S. air quality regulatory system, which focuses on three major air pollutant sources: industrial ("stationary"), mobile, and area sources. The combined emissions of VOCs, SOx, NOx and PM from these sources lead to a wide range of air pollution problems such as tropospheric ozone, fine particulates, acid deposition, and visibility impairment. Using the "one-atmosphere" approach to assess and regulate these air quality issues improves the effectiveness of management practices and provides comprehensive assessments that facilitate the calculations of environmental benefits relative to economic impacts.

For more information on modeling visit http://www.epa.gov/air/aqmportal/management/modeling/index.htm. For additional information on CMAQ, please visit http://www.epa.gov/asmdnerl/CMAQ/index.html.

e. Control Strategies

Control strategy development is the process of assessing specific abatement measures, management practices, or control technologies to determine the best combination of approaches to provide the emission reductions necessary to achieve the air quality standard or goal. Three primary considerations in designing an effective control strategy are:

1. Environmental: factors such as equipment locations, ambient air quality conditions, adequate utilities (i.e., water for scrubbers), legal requirements, noise levels, and the contribution of the control system as a pollutant;
2. Engineering: factors such as contaminant characteristics (abrasiveness, toxicity, etc.), gas stream characteristics, and performance characteristics of the control system; and
3. Economic: factors such as capital cost, operating costs, equipment maintenance, and the lifetime of the equipment. Air pollution officials should also consider pollution prevention which includes eliminating as much of the pollution emissions as possible at the source, substituting raw (and less toxic) materials, considering alternative manufacturing processes, and improving process control measures.

Controls on major stationary, mobile, and area sources are part of a successful control strategy. These controls should utilize reasonably available control technology. Examples include controls on volatile organic compounds from solvent and paint usage as well as controls on nitrogen oxide emissions from combustion units. For mobile sources, examples include tighter emission controls for vehicles and low-sulfur fuel standards. For major stationary sources, it is beneficial to issue permits including emission limitations for any major sources, new and existing. The basic types of emission control technology are mechanical collectors, wet scrubbers, bag houses, electrostatic precipitators, combustion systems (thermal oxidizers), condensers, absorbers, adsorbers, and biological degradation. The selection procedure should be based on the environmental, engineering, and economic considerations described above.

Initially, the air quality management process should focus on obvious sources of air pollution and the quickest means of control - more sophisticated and comprehensive strategies can be developed over time. Innovative strategies such as emissions trading, banking, and emissions caps can be incorporated as a further refinement as the strategy continues. These strategies may be used in addition to the "command-and-control" type regulations which have traditionally been used by air pollution control agencies. Local and regional control measures are both necessary for a successful strategy.

A control strategy developed by a local government may include locally appropriate measures, as well as control measures that the national government mandates be implemented nation-wide. Successful control strategies are usually adopted into a regulatory program with implementation deadlines and mechanisms for enforcement. Different control measures may be mandated at different levels of government, from local to state to national. In general, regulations established at the national level tend to have the most benefit while minimizing boundary and competition issues. The goal for all control strategies is to achieve real and measurable emission reductions.

There are four main steps in developing a control strategy:

1. Determine priority pollutants. The pollutants of concern for your location should be based on health effects and the severity of the air quality problem;
2. Identify control measures. For specific source categories, choose the appropriate controls based on the priority pollutants identified. A good source for control technologies is U.S. EPA's Clean Air Technology Center. Also, the State and Territorial Air Pollution Program Administrators / Association of Local Air Pollution Control Officials (STAPPA/ALAPCO) has developed several documents that provide a menu of control options. To order any of these documents (listed below), visit the STAPPA/ALAPCO website:
    - Controlling Particulate Matter Under the Clean Air Act: A Menu of Options;
    - Controlling Nitrogen Oxides Under the Clean Air Act: A Menu of Options;
    - Meeting the VOC 15% Rate-of-Progress Requirement Under the Clean Air Act: A Menu of Options; and
    - Toxic Air Pollutants: State and Local Regulatory Strategies;
3. Incorporate the control measures into a plan. Using the control measures identified, create a written plan with implementation dates to formalize the strategy. It is important to adopt a regulatory program and include it in the plan so that control measures will be enforceable; and
4. Involve the public. As with the other management activities related to the AQM process, it is critical to contact the regulated community and other affected parties, as the public should be consulted as part of the strategy development process. This early consultation reduces later challenges and streamlines implementation.

In the U.S., individual states are responsible for this process and they develop their own plan (called the State Implementation Plan, or SIP) based on the air quality issues that are of concern in their region. The SIP is the federally-enforceable plan that identifies how that state will attain and/or maintain the primary and secondary National Ambient Air Quality Standards (NAAQS) set forth in the Clean Air Act (CAA). Each state is required to have a SIP which contains the control measures and strategies developed through a public process and is formally adopted by the state and submitted to the U.S. EPA. To supplement the SIPs, federal regulatory and support programs are also in place. These programs include:

- Prevention of Significant Deterioration (PSD);
- New Source Review (NSR);
- New Source Performance Standards (NSPS);
- National Emission Standards for Hazardous Air Pollutants (NESHAP); and
- Control of Acid Rain, Ozone Depletion and Mobile Source Controls.

For an overview of these programs, visit http://www.epa.gov/apti/course422/apc4b.html. For several examples, see the local and state implementation plans created for states and counties within U.S. EPA's Region 4 (one of ten EPA regions in the U.S.). These plans cover the control of all air pollution issues from industry and automobile emissions to open burning and more. Another example is given in the SIP Plan Summaries for the New England region of the U.S.

For a case study on the development of ozone and particulate matter control strategies in the U.S. state of California, see the control strategy chapter in the air quality management plan for the South Coast Air Quality Management District of California. This document is available in English, Spanish, Chinese and Korean.

For more information visit http://www.epa.gov/air/aqmportal.

f. Human and Environmental Assessment

Health and environmental assessments are conducted as part of an Air Quality Management program to quantify and monetize: 1) the impact of the existing or current state of emissions and air quality; and 2) the incremental impact of a specific policy or program to reduce emissions and improve the current state of air quality.

Determining how various pollutants may impacts human health and the environment requires input from a range of disciplines, such as toxicology, public health, health sciences and epidemiology. The U.S. EPA sets ambient standards and emission standards and develops regulations to help reduce these effects.

Effects directly on human health can include increases in the risk of death (mortality) or increases in the risk of experiencing an adverse health effect (morbidity). Adverse health effects can be divided into acute effects such as headaches or eye irritation which generally last only a few days, and chronic effects such as emphysema or asthma which are generally associated with long-term illness.

Environmental effects, including those causing indirect damages to humans, are quite diverse. Examples range from aesthetic damages, which result from contamination of the physical environment and include increased problems of odor, noise, and poor visibility, to productivity damages, such as reduced productivity of farmland, forests, and commercial fisheries. Environmental effects also encompass intrinsic or non-use damages including losses in the value people associate with preserving, protecting, and improving the quality of ecological resources.

As part of the regulatory development process, EPA conducts health and environmental assessments and applies methodologies for estimating the benefits of air pollution control regulations. Also known as a "economic analysis," this is a critical aspect of U.S. decision making. Another aspect of human and environmental assessment is risk assessment. Risk assessment is the scientific process of evaluating adverse effects and is usually geographically limited, though the defined geography can vary tremendously, for example local, regional and global. The following are key components of the assessment process:

- Human Health Effects: The U.S. EPA has a database of human health effects that may result from exposure to various substances found in the environment. This database is called the Integrated Risk Information System (IRIS) and will help provide information on chemical substances for use in risk assessments, decision-making and regulatory activities. The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences;

- Environmental Assessment: U.S. EPA's Environmental Assessment Resource Guide is a resource that includes scoping environmental issues, generating alternatives, identifying and analyzing impacts, implementing mitigation, and conducting decision making and post-decision analysis. Of particular interest are the World Bank Mitigation Tables that cover a variety of project types. This guide is aimed at environmental professionals, small communities, and concerned citizens;
- Risk Assessment: The U.S. EPA has several risk assessment guidelines that set forth recommended principles and procedures to guide scientists in assessing the risks from chemicals or other agents in the environment. For human health assessment, there are guidelines for cancer, chemical mixtures, developmental toxicity, exposure assessment, mutagenicity, neurotoxicity, and reproductive toxicity. For environmental impacts, the EPA has published Guidelines for Ecological Risk Assessment that are meant to be internal guidance for EPA and to inform the public and the regulated community regarding the EPA's approach to ecological risk assessment. In addition, U.S. EPA has prepared two citizen's guides on risk assessment: one on Risk Assessment for Toxic Air Pollutants and one on Evaluating Exposures to Toxic Air Pollutants;
- Economic Analysis: The U.S. EPA's Guidelines for Preparing Economic Analyses establish a sound scientific framework for performing economic analyses of environmental regulations and policies. They incorporate recent advances in theoretical and applied work in the field of environmental economics; and
- Public Participation: It is important to involve the public. As with the other management activities related to the AQM process, it is critical to contact the regulated community and other affected parties, as the public should be consulted as part of the process.

For more information visit http://www.epa.gov/air/aqmportal.

g. Compliance and Enforcement

Complying with environmental regulations is important in protecting public health and the environment. From a regulatory agency’s perspective, it is one of checks in the air quality management system. In the U.S., the U.S. EPA is responsible for enforcing and assuring compliance with environmental regulations and may delegate its responsibility to state, local and tribal governments. U.S. EPA’s compliance and enforcement efforts focus on assisting business and communities with compliance training and guidance. The U.S. EPA also partners with foreign governments, international organizations, and other federal agencies to help build enforcement and compliance capabilities in other countries, and to fulfill U.S. commitments under international agreements.

Compliance and enforcement programs encompass a range of actions and activities, some of which include:

- Compliance monitoring;
- Administrative, civil, and criminal enforcement;
- Compliance assistance;
- Compliance incentives and auditing;
- Planning and results;
- Data systems; and

- Environmental justice.

Resources

Compliance Assistance: The U.S. EPA as well as states and local agencies have developed numerous industry specific documents available to assist in the development of a compliance program. These are accessible in the National Environmental Compliance Assistance Clearinghouse. In addition, because many compliance and enforcement documents are industry or emission specific, please be sure to access the many resources listed below.

Compliance Inspections are a key element of a compliance program. The U.S. EPA offers an on-line training course for conducting environmental compliance inspections.

For more information visit http://www.epa.gov/air/aqmportal.

h. Evaluation of Effectiveness and Modification of Controls as Necessary

The steps of the air quality management process discussed so far are summarized below:

- The air quality objectives have been defined;
- Scientists, and analysts have used the best available tools to represent the relationships between sources and concentrations at the present time;
- Those same tools have been applied to represent as accurately as possible the future condition if no further controls are put in place;
- Analysts have estimated the amount of emissions reductions that are needed to achieve the air quality objective;
- Economists have applied analysis tools to estimate the costs of implementing various control strategies relative to the economic benefit that will be achieved by reaching the air quality objective;
- Policy decision-makers have agreed that the control strategy is in the best interest of the public health and welfare;
- A formal program has been created to implement the required emissions reductions from the identified sources or source categories; and
- A formal compliance and enforcement system has been put into place to ensure that the required emissions controls are being properly implemented.

While there is a high probability that the actions taken will reduce emissions and have an effect on ambient air quality, we must remember that all of the steps discussed above are subject to uncertainty. The control program might not achieve the desired results or progress toward the objective may be slower than expected. Therefore, evaluation and adjustment of the control strategies is a key step in the implementation of an air quality management plan. Air quality plans in the U.S. include a component known as Reasonable Further Progress or RFP. The actual improvement in air quality measured as either emissions reductions or lower ambient concentrations are compared against this RFP guideline. If progress is slower than anticipated the SIP will be reviewed and if changes are necessary the SIP can be changed.

In the U.S., air quality management plans include contingency plans that list a series of more stringent controls that can be implemented if the original plan is not achieving the desired results. Even after the desired air quality is achieved the area must still operate under and comply with a maintenance plan that includes sufficient controls to ensure that the air quality will not return to unhealthy levels as the population and economic activity increase in the future. Typically the plan will specify some key measurement that will serve as the trigger for implementing the contingency plan. Triggers consist of defined circumstances (e.g., exceeding a concentration limit for a defined period, a change in direction of the trend line with time, or greater than expected economic activity or mobile source use) under which contingency plans must be implemented.

i. Public Participation

Environmental management is the collective responsibility of individuals, communities, industries, businesses, organizations and institutions, governments, and countries. Increasingly, governments recognize the value and importance of participation by civil society in environmental management, and are responding to the public's desire to be included in decision-making processes on matters that affect them. Public participation involves actively seeking, and is viewed as integral to having an effective environmental management.

Citizens have greater access to information and are demanding to be more involved earlier in policy development processes. In many countries, data are available via the Internet and people can determine for themselves the sources of local pollution and use that information to influence governmental entities or the industry directly.

Educating the public and ensuring their participation in the environmental protection systems is a critical aspect of governmental responsibility. Air quality has such a tremendous impact on sensitive populations and they need to understand how they are affected, how they can minimize these impacts, and how they can influence decision makers for the benefit of all society.

U.S. EPA has information on public involvement that is intended to share information about public involvement activities across EPA and help users understand how different types of public involvement relate to EPA programs and how public input can be used in EPA decision-making processes. Important examples of how U.S. EPA provides environmental information to the public include:

- AIRNow Ozone and Particulate Matter Monitoring and Forecasting - the AIRNow site provides the public with easy access to national air quality information by offering daily air quality index (AQI) forecasts as well as real-time AQI conditions for over 300 cities across the U.S., and provides links to more detailed State and local air quality web sites. The AQI is an index for reporting daily air quality that tells you how clean or polluted your outdoor air is, and what associated health effects might be a concern for you. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air;
- Window to my Environment - this is a web-based tool that provides a wide range of federal, state, and local information about environmental conditions and features in an area of your choice within the U.S. The site includes interactive maps, statistical information and links to local resources;
- Envirofacts - Envirofacts offers a single point of access to select U.S. EPA environmental data. This website provides access to several EPA databases to provide you with information about environmental activities that may affect air, water, and land

anywhere in the United States. With Envirofacts, you can learn more about these environmental activities in your area or you can generate maps of environmental information; and

- The Public Participation Guide to Air Quality Decision-Making in California provides with the basic tools and information needed to understand and participate in the air pollution policy, planning, permitting, and regulatory decision-making processes in California.

4. Coordination Among Different Levels of Government

Implementation of a control plan and monitoring progress toward the established air quality goals is a complex process that requires coordination on many levels. In the U.S., the states are required to submit a formal plan to U.S. EPA that describes how air quality goals will be achieved. Larger states with many urban areas and different types of economies will often rely on local agencies to assist in the development and implementation of the plan. Large urban areas like Los Angeles, New York City, Atlanta and Houston have several air quality issues and their plan has to address all of the pollutants for which the area is designated nonattainment.

EPA provides guidance, conducts research, establishes policy, develops national-level regulations, and approves state air quality plans. Where particular pollutants emitted in one state and cross state boundaries to affect air quality in other states (e.g., ozone in the eastern U.S.), U.S. EPA has the authority to create multi-state transport regions and to facilitate coordinated programs to address the interstate transport issue. The process has evolved over the years and the relationships among the different levels of government are not exactly the same in all states. The program's overall effectiveness arises out of the certainty of both the air quality targets, and the responsibilities of officials at the various levels. The program operates with a strong national authority for standard setting and policy development. Given those national-level goals state and local agencies are responsible for the implementation and in many cases have a degree of flexibility in the implementation phase so that specific local economic conditions can be accommodated.

5. Review of AQ Management in the United States

a. A Brief History of U.S. AQ Management

The Growing Demand

Public awareness of air pollution and its effects, resulting from both chronic and episodic air pollution events, created the demand for local and state level air quality management. The first significant events caused by the combined influences of uncontrolled emissions by point sources, (steel mills, coke ovens, chemicals manufacturing, etc.) and meteorological patterns concentrating pollutants in a confined space over several days.

On October 28, 1948 in Donora, Pennsylvania, emissions of SO_2, CO, NO_x and particulate matter from a series of steel and metallurgical operations were trapped in a mountain valley by a strong temperature inversion and stagnant winds. The pollution became so concentrated that the sun was hidden, and streetlights were necessary at noon on the second day of the episode. That afternoon, spectators at the local high school football game could not see the players on the field. Four days later the winds picked up and moved the pollutants out of the valley leaving 20 people dead and over 7,000 people, approximately half of the town's population, suffering severe respiratory distress.

This event and others that were less severe raised general public awareness of air pollution and the role of air pollutants as a public health issue. As a result, initial efforts were introduced to address air quality problems through the 1950s and 1960s. Despite the efforts of agencies organized to address environmental problems, economic growth during this period caused increased air, water and solid waste pollution. Concentrations of air pollutants in the large cities became high enough to cause effects on generally healthy people and releases of organic liquids were so prevalent that some rivers in industrial cities would occasionally catch fire. Rachel Carson published her book, Silent Spring, in1962 to raise awareness of the negative effects of wide scale pesticide use on ecosystems and wildlife. These and other events collectively contributed to the rise of environmental awareness in the United States. In response, Presidents and members of Congress began to discuss the role of the federal government in overseeing environmental protection activities.

Early Attempts at Federal Air Quality Legislation

The earliest air pollution remediation efforts, including the Clean Air Act of 1955, are considered failures by most observers. The most often cited criticisms of pre-1970 practices are:

- A vague definition of air pollution;
- Too little emphasis on protecting public health relative to the emphasis on technological and economic feasibility; and
- Weak federal participation resulted in reliance on state and municipal public health agencies to solve the problems.

For example, the enabling language of pre-1970 legislation set 'feasible' emission standards for new vehicles; however, permitted air quality standards to vary by state and provided no specific deadlines for attaining the standards. Further, legislation relied solely on state enforcement (except for a cumbersome conference procedure between federal, state, municipal and business groups), and ignored controlling emissions from new stationary sources and from growth in transportation systems.

Significant Accomplishments of Air Quality Management in the United States

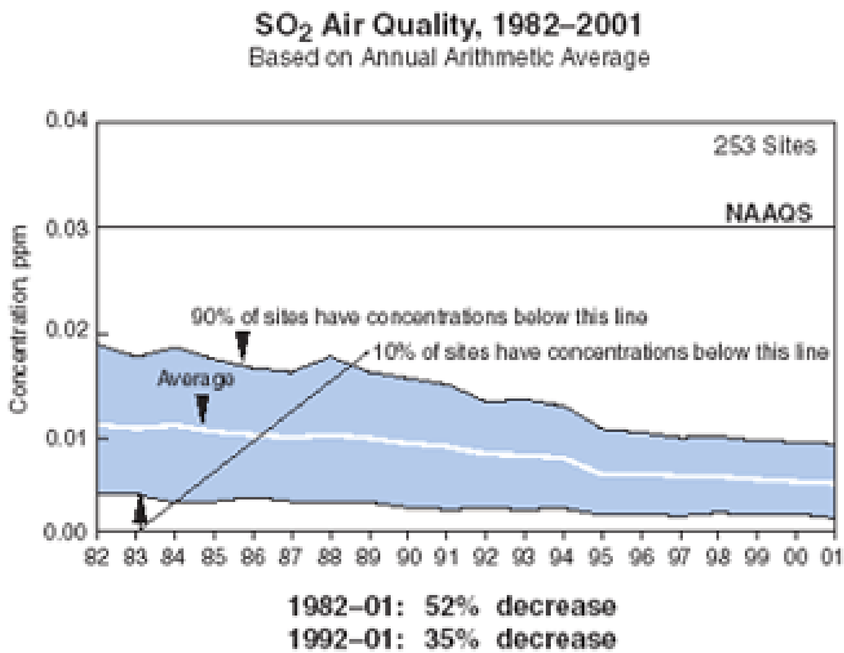
Initial air quality management efforts in the United States focused on three main activities. Events like those in Donora, Pennsylvania clearly established the need for aggressive programs to control particulate matter and SO_2 emissions from coal combustion and other industrial sources. The rapid increase in automobile ownership and miles driven as suburban development expanded through the 1950s and 1960s required a national program to reduce the emissions from highway vehicles. Lastly, the combination of emissions of NO_x and VOC in many industrial and developing urban areas was resulting in the formation of smog and brown clouds over urban areas. It was known that this condition resulted from photochemical oxidation processes involving NO_x, VOC and sunlight. Initially, the air quality management goal was to reduce concentrations of the collection of photochemical oxidants that are formed in these systems. Subsequently, the goal shifted to focus on the dominant photochemical oxidant, ozone (O_3), and a national program was implemented to reduce the ambient O_3 concentrations.

Control of SO_2 and Combustion Related Particulate Matter

Addressing emissions of particulate matter and SO_2 from large boilers was relatively easy. The appropriate control systems were large and expensive to install, but adequate technology was available and there were relatively few technological or operational hurdles to implement these control approaches. Particulate matter emissions were reduced by the use of filtration and electrostatic removal systems, and SO_2 reductions were achieved by changing to cleaner fuels or by installing sulfur scrubber devices. It was not long before emissions reduced significantly and air quality problems associated with the build up of smoke and SO_2 in the United States are rare.

Even though fuel consumption and economic activity continue to grow in the United States the average concentrations of SO_2 and visible particulate matter released as smoke from combustion activities have decreased markedly as a result of the Clean Air Act. Figures II-8 and II-9 show how the ambient concentrations of SO_2 and PM-10 have changed since the early 1990s.

Figure II-8. Observed Trend In SO_2 Concentration Data

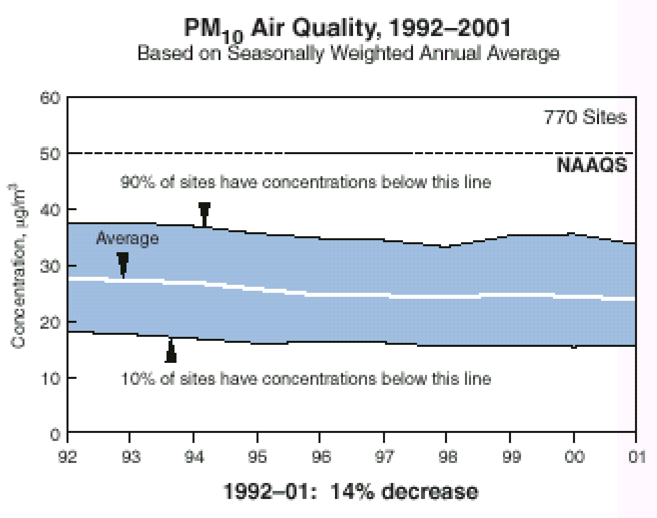


Control of Emissions From Mobile Sources

EPA research programs have had a significant effect on the quantity of air pollutants released from an individual car. The emissions of VOC and CO from highway vehicles are approximately half of the total in 1970 and NO_x emissions have remained about the same. This is despite the fact that the vehicle miles traveled have increased by almost 150% during that same period. These impressive results have been achieved through a variety of approaches. Some of the steps that have been taken are listed below:

- Engines have become more efficient and inherently cleaner;
- Catalytic control devices have been installed on each individual car to decrease emissions;
- Fuels have been improved to burn more efficiently and cleaner;

Figure II-9. Observed Trend In PM-10 Concentration Data



- Inspection programs have been implemented to find the cars that have faulty control systems and to correct those problems;
- Traffic flow improvements have been made to reduce congestion;
- Mass transit systems have been built in many large urban areas;
- Vehicles with alternate propulsion systems are being developed and tested; and
- Steps have been taken to reduce emissions from off-road mobile engines.

Almost all of the mobile source control programs are planned and implemented on a national level. The obvious reason is to standardize the types of engines and fuels so that car manufacturers don't have to make and sell different cars to meet different standards in different states. Many of the programs, such as vehicle inspection programs, mass transit, and traffic flow improvements, however, are still implemented on a state and local level.

Efforts to Reduce Ozone Concentrations

From an air quality management perspective the control of ozone concentrations in U.S. cities has been an extreme challenge. There are large and growing urban areas in the United States that have climates that are conducive to ozone formation. In the Northeastern United States the region between Washington, DC and Boston, Massachusetts is highly populated with significant amounts of traffic, trade, and commercial activity. The Northeastern region, sometimes called the urban corridor, is also downwind of the Ohio and Tennessee River Valley areas where a large amount of the electric generation capacity is located. These factors work together to produce ozone despite the significant efforts that have been implemented to reduce emissions from local industrial and commercial sources. Given the increases in vehicle miles driven, and other economic activity over the past 20 years, there have been significant successes. The VOC and NO_x emissions reductions associated with mobile sources, and VOC controls resulting from the reformulation of a variety of products that once contained organic solvents have reduced the peak concentrations of ozone, and average ozone concentrations have remained relatively steady during this period. Figure II-10 and II-11 show the observed trends over the past 20 years in the second highest hourly average (representing the peak concentration) and fourth highest hourly average (representing the ambient concentration goal), respectively.

Continuing the Progress

EPA and the many other stakeholders interested in air quality management continue to identify the new and emerging air quality management priorities and to develop approaches to address

Figure II-10. Observed Trend in Peak Ambient Ozone Concentrations

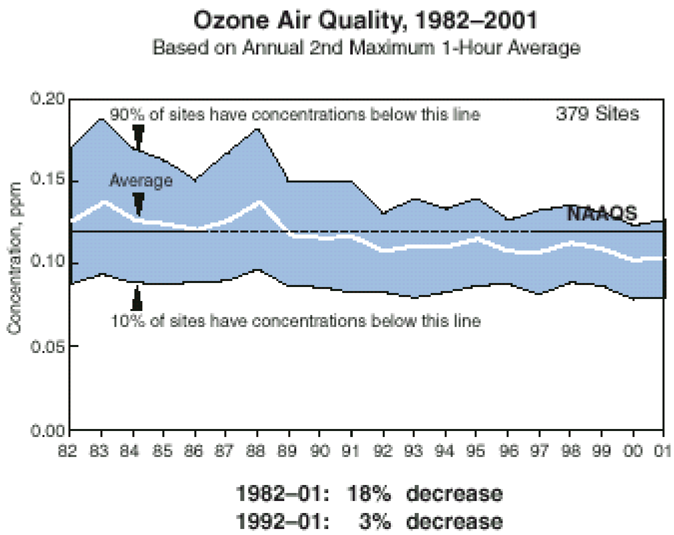
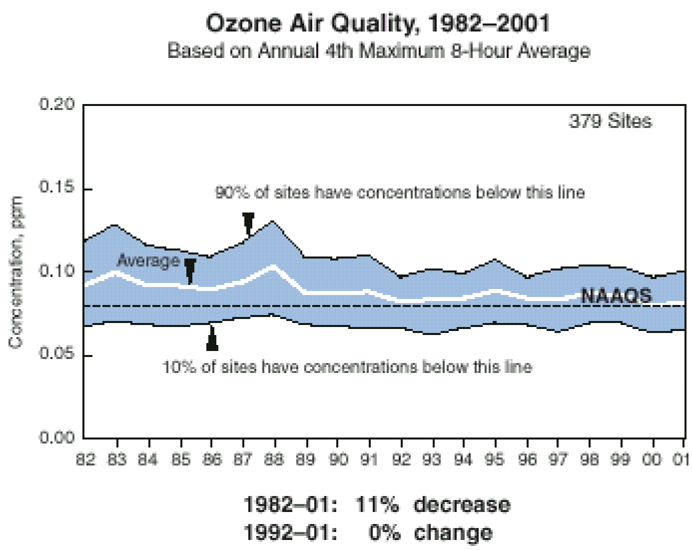


Figure II-11. Observed Trend in Ozone Concentration Relative to the Air Quality Goal



these issues. The process involves exploring and understanding the science that affects the problems, evaluating options for reducing the problems, estimating the costs and benefits of various control programs, monitoring the results, and documenting the experiences. Some of the other successes of air quality management programs and the emerging issues are listed below:

- Carbon monoxide (CO), one of the pollutants that is subject to the national air quality standards, concentrations have been reduced by about half and nearly all areas that have been in violation of the air quality standards are now in compliance. This is despite the increase in vehicle traffic, the dominant source of CO;
- Concentrations of nitrogen dioxide (NO_2), also one of the original pollutants subject to national air quality standards, have been reduced steadily and now all areas that were in violation of the standard are in compliance;
- Lead (Pb) was a significant air quality problem in most urban areas before unleaded gasoline regulations were put in place. Lead was taken out of gasoline primarily because it poisoned the catalyst in vehicle exhaust control systems. Once lead was removed from gasoline the air concentrations fell precipitously and all but a few areas, in the immediate vicinity of lead processing facilities, now meet the air quality standards for lead;
- Despite the successes in controlling VOC and PM emissions, concentrations of some specific organic pollutants and particulate containing heavy metals still present a health risk to selected communities. U.S. EPA has been implementing an aggressive program to develop and apply technology based standards to over 80 individual industry segments to control emissions of the 188 listed hazardous air pollutants (HAP) over the past 10 years. The program is nearly complete and when fully implemented the net effect will be to reduce approximately 1.5 million tons per year of HAP emissions in the United States;
- Initially, programs to reduce population exposure to SO_2 resulted in the location of some large sources in rural areas, and the use of tall stacks. The successes associated with SO_2 control programs, however, resulted in sufficient SO_2 emissions that could be transported over 1,500 kilometers or more and ended up contributing to acid deposition. U.S. EPA developed and implemented an innovative control system based on marketable emissions allowances and established a trading system to promote the exchange of these allowance among affected facilities. The program resulted in a reduction of SO_2 emissions from electric generating facilities by nearly half at costs that are much lower that would be expected through a traditional facility specific regulatory program;
- EPA has implemented programs to comply with the Montreal Protocol to reduce the use and emissions of a list of chemicals that can destroy the upper atmosphere ozone layer;
- EPA has many programs in place to monitor emissions of greenhouse gases, encourage energy efficiency, and to conduct research into the causes, consequences and potential strategies to mitigate climate change;
- EPA has implemented many programs to assist local emergency response teams to quickly and efficiently address accidental releases of dangerous air pollutants;
- EPA conducts research and assists property owners in understanding and mitigating the effects of exposure to air contaminants in indoor environments; and
- Finally, U.S. EPA participates in multinational programs to cooperate on global and regional air quality issues.

b. Evolution of the Legal Framework

1970 Clean Air Act

Air quality management (AQM) in the U.S. began in earnest with passage of the Clean Air Act in 1970. Earlier efforts to address the nation's air pollution problems, which started with the Clean Air Act of 1955, are considered failures by most observers for the reasons listed earlier. The 1970 CAA established a new philosophy based on setting national goals, and a more formal definition of federal and state responsibilities. Federal authority for oversight of air quality programs was placed in the newly created Environmental Protection Agency. The 1970 CAA established protection of public health as the unambiguous objective of AQM. Air quality standards are established without consideration of economic and technological feasibility. If technology were inadequate or uneconomic, it would have to catch up. For many years after 1970, however, claims of technological and economic barriers continued until sufficient knowledge was produced and experience was acquired to overcome historical inertia and uncertainty. During this period, doubts were resolved in favor of health and the environment.

In summary, the 1970 Amendments had the following effects:

- Implemented a more comprehensive and coherent approach for managing the nation's air quality;
- Confronted the multi-institutional and jurisdictional situation of controlling air pollution.
- Expanded and extended the role of the federal government; and
- Brought planning and technology forcing into the new philosophy of pollution control, despite the high degree of uncertainty associated with both.

The ambition of the 1970 CAA is expressed by requirements to:

- Reduce emissions from new automobiles by 90% within five years;
- Establish (i) emission standards for new or modified existing sources if the sources are among a list of more than 60 source categories, and (ii) emission limitations for sources of hazardous air pollutants; and
- Define and achieve adequate air quality through a three-step process that required (i) U.S. EPA to set standards for all pollutants that endangered the public health or welfare, (ii) states to submit detailed control plans adequate to meet standards by a certain date (if the standard aimed to protect the public health) or by a reasonable time (if the standard aimed at protecting public welfare), and (iii) all adopted control measures would be legally enforceable in both federal and state courts.

The 1970 CAA required U.S. EPA to set National Ambient Air Quality Standards (NAAQS) to protect the public health with an adequate margin of safety. Initially, NAAQS standards were set for ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), and total suspended particulate matter (TSP). The initial legislation required that all areas achieve air quality consistent with the NAAQS within 5 years, but allowed areas an additional 5 years if existing controls were inadequate to bring all areas into attainment. Volatile organic compounds (VOC), one of the precursors for O_3 formation was also listed as a guideline pollutant. The initial strategies to control O_3 depended almost entirely on controlling VOC and it was listed to stress the importance of implementing emissions control technologies on sources of VOC. Through the years, lead (Pb) has been added to the list of NAAQS pollutants, and the standards for particulate matter have been revised to consider the size ranges of particulate matter mass. The initial requirements for NAAQS pollutants, however, are still the legal foundation for air quality management.

The emissions limitation requirements on new sources were known as new source performance standards (NSPS) and were adopted to ensure continuing air quality improvements as facilities upgraded existing and replaced old technology. The NSPS concept was intended to avoid the burden of excessive costs to convert existing facilities to systems with improved emissions control capabilities.

The 1977 CAA Amendments

By 1975, it was clear that the timetables established for reaching the NAAQS were too aggressive. The act was amended in 1977 to extend the time allowed to achieve compliance with the NAAQS, and to extend the time allowed to achieve the necessary level of emissions reductions from automobiles. While compliance with the NAAQS, and implementation of NSPS regulations was retained as a state and local authority, the federal government continued to assume the authority for setting standards for mobile sources.

Additional requirements associated with the 1977 CAA amendments included the initiation of reasonably available control technology (RACT) on many of the sources that were contributing to nonattainment problems in urban areas. A control technology does not have to result in the absolute lowest possible emission rate to be considered RACT. This program was intended to achieve the amount of control that could be realized relatively quickly at reasonable cost on existing sources before they were modified or replaced. Most RACT controls were applied to sources of VOC in an attempt to improve O_3 air quality, although RACT controls also were applied to sources of CO, SO_2 and PM.

The new source review program was also introduced in 1977. New source review (NSR) was applied at the facility level to a variety of identified source category types. NSR was another control program that applied to new and modified sources, with the intention of creating a continuous improvement in air quality as existing facilities were retired and replaced. NSR consists of two components, one operating in nonattainment areas and one operating outside of nonattainment areas. Nonattainment area NSR requires control technology that meets the lowest achievable emission rate (LAER) definition. In addition, NSR requires emissions offsets for any increase in emissions caused by the new or modified source in nonattainment areas. The offset program requires that emissions be reduced somehow within the nonattainment area by an amount greater than the total increase caused by the new facility. For example, if the offset requirement is 10%, a source that will increase emissions by 100 tpy must identify source controls that will reduce emissions by 110 tpy.

To discourage companies from building all of their new facilities in areas just outside of the nonattainment area, and to keep relatively clean areas from becoming unhealthy, the NSR program also applied to affected sources built in attainment areas. This program is known as prevention of significant deterioration (PSD). Under this program new sources in attainment areas must acquire a construction permit that specifies emissions controls that meet the best available control technology definition, and demonstrate that the net increase in emissions will not contribute significantly to air quality problems in the attainment area or in nearby nonattainment areas. The PSD program does not, however, require emissions offsets of the type required for nonattainment NSR.

EPA initiated a program to assemble and maintain a compilation of control technologies that had been approved for the various programs. The system is currently referred to as the RACT/BACT/LAER Clearinghouse. It offers an Internet based system through which users can identify the complete list of available technologies that are applicable for given industries and situations. This service can decrease the time and effort required by facility owner/operators to identify the alternatives available for meeting their control requirements.

The 1977 amendments also added a control program specifically for individual compounds that were identified as hazardous air pollutants (HAPs). HAPs are treated separately from NAAQS pollutants because they are often confined to specific areas where one or more large sources can cause a local health effects problem. The underlying principle of the program required the implementation of national emission standards for hazardous air pollutants (NESHAPs), set at levels that would protect the public health with an ample margin of safety.

The 1990 CAA Amendments

Continued implementation of the 1970 act and the 1977 amendments through the 1980s resulted in significant improvements in air quality in many urban areas in the United States. Some of the large cities, however, continued to observe concentrations in excess of the NAAQS standards, particularly for O_3 and PM_{10}. In addition, the regional nature of ozone, PM_{10}, acid rain, and visibility air quality was becoming increasingly apparent. The implementation of NESHAPs to control hazardous air pollutants was largely unsuccessful, primarily because it proved difficult to establish absolute levels of control and exposure that were sufficiently protective of health. Finally, the relationship between U.S. EPA and the state and local agencies was strained largely because of the costs associated with maintaining the programs that were mandated by federal rules.

Congress passed the Clean Air Act Amendments of 1990 in part to correct some of the weaknesses of the earlier act and in part to recognize new air quality problems and management approaches. For some aspects of air quality management, the 1990 CAA represented a significant departure from the methods and approaches that had been used to address air quality in the past. The adoption of these amendments represents the current legal basis for AQM in the United States. Some of the significant new approaches included in the 1990 act are listed below:

- The first national, market-based emissions control program based on an emissions cap and marketable emission allowance trading system was established. The program was designed to apply to SO_2 and NO_x emissions from large fossil fuel burning boilers for the purpose of controlling the formation of acidic precipitation. The program has resulted in significant reductions of SO_2 and NO_x emissions at a cost per ton removed that is much lower than that predicted for a standard command and control approach;
- Areas that are in violation of NAAQS were formally classified based on severity of the air quality in the area relative to the level of the NAAQS. In this approach, more stringent and aggressive control requirements are demanded as the classification increases from lowest to highest severity. In addition, the areas with the higher classifications were given more time to comply with the NAAQS than those areas that were just marginally over the NAAQS;
- A new program was implemented to reduce emissions of HAPs. The new program was based on maximum achievable control technology (MACT). The MACT control requirement is based entirely on the available, proven, cost-effective technology, and not on health

considerations. This program has significantly reduced the emissions of HAP pollutants throughout the country;

- Following the implementation of all defined technology-based MACT standards the new act requires a follow-up review of the remaining risk to populations from these HAP pollutants. Additional controls will be required to reduce this residual risk associated with sources of HAPs;
- The first formal organization of a group of States was established to address persistent violations of the NAAQS for ozone in the densely urbanized Northeastern United States. Under this program local and state air quality management agencies from the Washington, DC area through New England were given a mandate to coordinate on air quality planning issues. The act also encouraged the formation of other multi-state planning groups to address other regional air quality issues;
- The act recognized the need to address visibility degradation at national parks and other scenic wilderness areas. The focus is on processes that result in the formation of fine particulate matter on a regional scale at size ranges that effectively scatter and absorb light. U.S. EPA also established a separate coalition of states, known as the Grand Canyon Visibility Transport Commission, to study the causes of and develop common recommendations to address visibility degradation at the National Parks and wilderness areas on the Colorado Plateau (Grand Canyon, Canyonlands, Bryce Canyon, Petrified Forest, Mesa Verde, and Zion National Parks). The Clean Air Act allows visibility degradation to be addressed as an air quality problem that affects the public welfare;
- The act enhanced efforts to reduce or eliminate the use of certain stratospheric ozone depleting compounds in compliance with international agreements. The act also established programs to quantify the national emissions of greenhouse gases on an annual basis;
- The act established the mechanisms for regulating emissions from non-highway mobile sources, and to set standards for fuel characteristics and fuel additives to achieve improvements in the efficiency and/or emissions characteristics from mobile sources; and
- The 1990 act also created a new operating permit program. Under this program all major and many minor sources are required to obtain a permit to operate. The operating permit establishes emissions limits based on the applicable emissions standards and relevant air quality objectives of the local communities in which the sources operate. The operating permits program established an emission fee system that allowed the state and local agencies to charge sources for their emissions to generate funds to implement and maintain the program. The operating permit program also simplified the response of both the regulating agencies and the regulated sources by collecting all relevant permit conditions into a single mechanism. Once the operating permit is approved it then becomes an enforceable component of the SIP and ultimately can be federally enforceable if the state fails to fully implement the program.

Stability and Longevity of the CAA

The CAA has only been amended on two occasions during the 33 years it has served as the legal basis for air quality management in the United States. In both cases, the dominant reason for amending the act was to extend its authorization beyond those dates that were intended to mark the solution of the air quality problems that have proven to be difficult to attain. Clearly, this experience suggests that the successful resolution of air quality problems in growing industrial societies is not an easy task. It also offers a lesson in how to approach and implement a challenging technical program. The legislation sets broad goals and establishes the framework for a responsible approach to achieve results. The authority and responsibility for developing the implementation rules, however, is given to a body of scientists and engineers with the training and experience to understand the technological demands and constraints on the various implementation options. This approach in concert with the checks and balances afforded through the courts is one successful model under which such a program can continuously achieve progress toward goals for the public benefit without causing unreasonable hardships for state and local governments, industries, or citizens.

c. Institutional and Organizational Structure

Currently, the U.S. Environmental Protection Agency employs 18,000 people in the headquarters, regional and laboratory offices around the country. U.S. EPA has responsibilities for the protection of the water, air, and land surface for the benefit of the American people. All 50 States and many local agencies also employ professionals that monitor conditions and implement programs to assist in the identification and correction of environmental problems. Although Congress gives U.S. EPA the authority and legal basis to implement environmental management programs, the agency operates under the executive branch, and the Administrator of U.S. EPA is appointed by the President.

In addition to administrative activities, there are eight functional components. Each of these components is led by an Assistant Administrator who is also appointed. The functional components are:

- Office of Air and Radiation;
- Office of Enforcement and Compliance Assurance;
- Office of Water;
- Office of Solid Waste and Emergency Response;
- Office of Research and Development;
- Office of Prevention, Pesticides and Toxic Substances;
- Office of International Affairs; and
- Office of Environmental Information.

The Office of Air and Radiation (OAR) oversees U.S. EPA's air quality program including national programs, technical policies, and regulations. Through research and technical assistance, the Office of Research and Development (ORD) provides much of the scientific foundation for OAR and its regulatory decisions by assessing the state of the environment, identifying and conducting basic research on new issues of potential concern, and providing information and tools to support risk-based decisions. The Office of Enforcement and Compliance Assurance (OECA) works with U.S. EPA Regional Offices and other government agencies to ensure compliance with the nation's air laws. The Office of Environmental Information coordinates data collection and dissemination of that information to the public and the agencies that cooperate with U.S. EPA. The focus of these activities is on electronic data exchange, taking advantage of the efficiencies offered by making information available through the Internet. The principle roles and organizational structure of these U.S. EPA offices are briefly discussed in the following paragraphs.

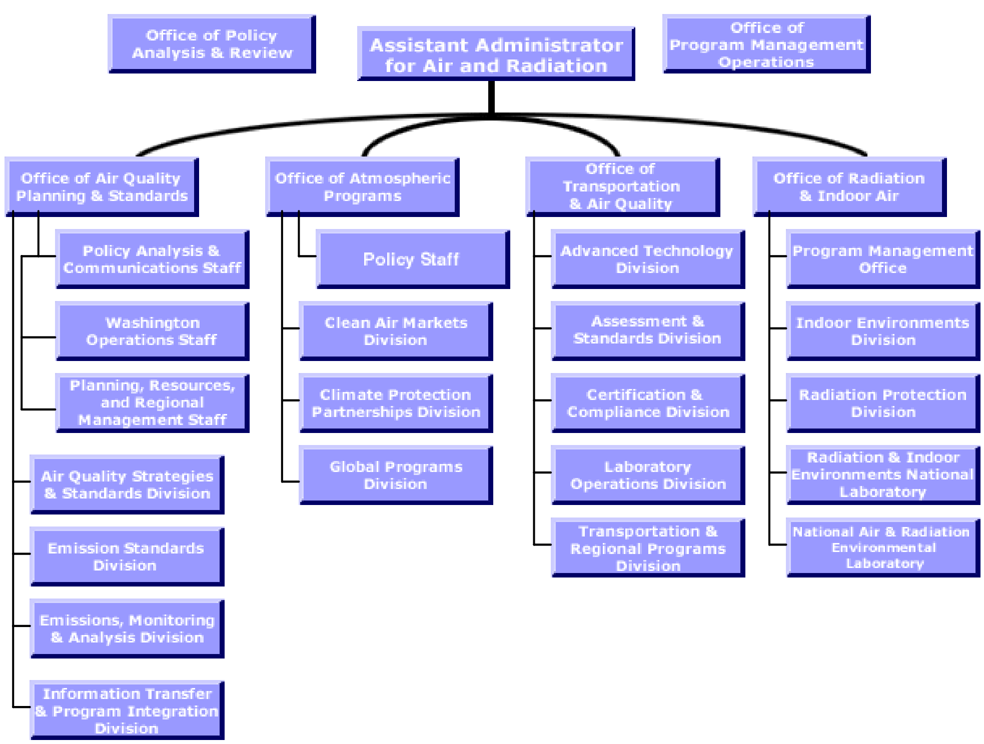
Office of Air and Radiation

The Office of Air and Radiation (OAR) is responsible for the programs, policies, and regulations related to air activities. The organizational structure for OAR is depicted in Figure II-12. There are three offices underneath OAR that are responsible for the office's policy and management, the: 1) Assistant Administrator for Air and Radiation; 2) Office of Policy Analysis and Review; and 3) Office of Program Management Operations. Four offices carry out OAR programs, which are the: 1) Office of Air Quality Planning and Standards; 2) Office of Atmospheric Programs; 3) Office of Transportation and Air Quality; and 4) Office of Radiation and Indoor Air. Each of the four program offices is further organized into various divisions, laboratories, and other staff groups. The roles and responsibilities of the four program offices are described in more detail in this section. The policy and management offices roles are generally related to oversight of the processes associated with decision-making, oversight and communication of the policy direction and implementation of programs. These functions will be described in the following section.

Office of Air Quality Planning and Standards

The Office of Air Quality Planning and Standards (OAQPS) is described in detail in this chapter primarily because it is responsible for attaining NAAQS and implementing risk analysis and reduction programs for air toxics. These two goals account for over 95 percent of the allocated budget under the Clean Air strategic goal. There are currently about 370 people employed within OAQPS under the management staff and four program office divisions.

Figure II-12. U.S. EPA Office of Air and Radiation - Organizational Chart



The four divisions within OAQPS are the 1) Air Quality Strategies and Standards Division; 2) Emission Standards Division; 3) Emissions, Monitoring, and Analysis Division; and

4) Information Transfer and Program Integration Division. These four program office divisions are organized into groups, as shown on Table II-6. Each group has approximately 10-20 employees.

The Air Quality Strategies and Standards Division (AQSSD), which consists of about 60 people, develops national and geographically focused strategies and programs for air quality management based on assessments of health and ecological effects, exposure and risk, and economic impacts and benefits. Such assessments support the development of criteria pollutant ambient standards programs and emission standards under the Clean Air Act, and the integration of various aspects of the criteria pollutant and hazardous air pollutant programs in coordination with other OAQPS divisions.

More specifically, the AQSSD manages the review and revision of NAAQS and develops attainment and maintenance strategies, policies, and implementation programs. The division serves as program source for expertise on health and ecological effects and the analysis of exposure and the risks associated with exposure to air pollution.

Table II-6. Divisions and Groups Under the Office of Air Quality Planning and Standards

Air Quality Strategies and Standards Division	• Health & Ecosystem Effects Group • Integrated Policy & Strategies Group • Innovative Strategies & Economics Group • Ozone Policy & Strategies Group
Emission Standards Division	• Coatings & Consumer Products Group • Combustion Group • Metals Group • Minerals & Inorganic Chemicals Group • Organic Chemicals Group • Policy, Planning, & Standards Group • Risk & Exposure Assessment Group • Waste & Chemical Processes Group
Emissions, Monitoring, and Analysis Division	• Air Quality Modeling Group • Air Quality Trends Analysis Group • Emisson Factor & Inventories Group • Monitoring & Quality Assurance Group • Source Measurement Analysis Group • Source Measurement Technology Group
Information Transfer and Program Integration Division	• Education & Outreach Group • Integrated Implementation Group • Information Management Group • Information Transfer Group • Operating Permits Group • Program Implementation & Review Group

The AQSSD also serves as program source for expertise on benefits assessments and economic and regulatory impact analyses, including impacts on small entities and environmental justice, and economic incentive programs. It conducts such analyses in support of OAQPS-wide standards, rules, and strategies, as well as in conjunction with U.S. EPA-wide assessments. Through its guidance, the AQSSD develops and promotes the application of innovative, incentive-based regulatory strategies. The division establishes and maintains cooperative working relationships with regional, state and local agencies, as well as selected stakeholders (industry, environmental groups, etc.), to facilitate effective development and implementation of regulations, policies and guidance. It also works closely with other OAQPS divisions and U.S. EPA offices to ensure integration of rules, policies and guidance to facilitate effective implementation.

The Emission Standards Division (ESD), which consists of approximately 100 people, is responsible for establishing emission standards (under the Clean Air Act) and managing federal programs for nationwide control of hazardous and criteria pollutant emissions from stationary sources. This division develops and implements emission standards for hazardous and criteria air pollutants, new source performance standards, control technique guidelines, alternative control techniques documents, and guidance for implementing standards at the state and local level. It also conducts comprehensive studies of stationary source categories to determine the nature and magnitude of air pollution emissions, control methods, operational and administrative procedures, and economic aspects of control.

The ESD is responsible for providing technical assistance to other divisions in OAQPS, other offices in U.S. EPA, state, and local agencies, small and large businesses, international organizations, and the public on effective control technologies and associated costs. It develops overall plans, strategies, and policies addressing regulatory programs for stationary sources of air toxics and criteria pollutants and new, innovative, and streamlined approaches to regulatory development (including coordinated strategies for co-control of hazardous and criteria air pollutants).

Finally, the ESD establishes and maintains cooperative working relationships with regional, state, and local agencies, as well as selected stakeholders (industry, environmental groups, etc.), to facilitate effective development and implementation of regulations and guidance.

The Emissions, Monitoring, and Analysis Division (EMAD), which consists of approximately 100 people, is responsible for directing a national program of scientific, technical, and policy guidance for U.S. EPA headquarters, regional offices, and state and local agencies, in air quality monitoring and modeling, control strategy demonstrations, and emissions measurement. In particular, the division:

- Develops and distributes guidelines for air quality models and provides technical assistance in applying the models;
- Develops and distributes guidance on air quality and source monitoring;
- Establishes air quality indicators of progress, analyzes air pollution trends, and distributes information on progress in reaching air quality goals;
- Conducts control strategy demonstrations, source monitoring, and ambient monitoring for OAQPS;
- Develops new methods for ambient monitoring and modeling and develops and issues guidance and training materials to apply them;

- Develops emission factors and provides technical guidance on emission inventories; and
- Conducts source testing and develops new source test methods for use by regional, state, and local clients.

The EMAD analyzes air quality data for use in program evaluation and coordinates development and use of emission inventories in program evaluation. It promotes the integration and simplification of information and data management systems. It also serves as a source of technical expertise for OAQPS and provides technical support to regional, state, and local clients on source testing and methods. Two major publications of the division, released annually, describe the current status and multi-year trends in emissions and ambient levels of air pollutants – the National Air Pollutant Emission Trends report and Air Quality Trends report.

The Information Transfer and Program Integration Division (ITPID), which consists of approximately 90 people, serves as the principal focus for management and transfer of air pollution control information and the integrated implementation of OAQPS programs, including operating permits. In carrying out these functions, this division manages design, development, maintenance, and evaluation of information systems, hardware, software, and other means of distributing key air pollution control information to government and non-government clients and the public at large.

The ITPID also develops and delivers training courses and educational materials on various technical and management aspects of air pollution control to U.S. EPA, state, local, industry, and other relevant stakeholders and assists other OAQPS and air program offices to conduct technical training workshops and transfer critical guidance and information to program clients.

In cooperation with other divisions and programs, the ITPID promotes the integration and simplification of information delivery and data management systems. The division manages and assures the integration of the national air quality permit programs, including operating permits, new source review, and prevention of significant deterioration. ITPID manages the implementation and integration of air toxics programs with operating permit programs to assure programs' requirements merge as smoothly as possible.

Office of Atmospheric Programs

The mission of the Office of Atmospheric Programs is to implement the cross-cutting atmospheric programs, such as the acid rain program, climate protection program, and ozone layer protection program. This is accomplished via three divisions: the Clean Air Markets Division, Climate Protection Partnerships Division, and Global Programs Division.

The Clean Air Markets Division (CAMD) is responsible for promoting market-based control strategies that provide regulated facilities and regulatory agencies additional flexibility to achieve air quality goals. CAMD grew out of the Acid Rain Division, which was created in 1990 to implement the highly successful SO_2 allowance-trading program for acid rain control. This division also has other programs that employ cap-and-trade mechanisms to address other environmental problems that are based on the experience gained while developing and operating the market-based Acid Rain Program.

The Climate Protection Partnerships Division (CPPD) runs energy efficiency partnership programs that focus on reducing greenhouse gas emissions through implementing voluntary energy efficiency programs. The programs are designed to be profitable, public-private partnerships. Examples of programs of the CPPD include the: AgSTAR Program, Aluminum Industrial Partnership Program, Coalbed Methane Outreach Program, Energy Star Programs, Buildings and Greenlights Partnership, Landfill Methane Outreach Program, Natural Gas STAR Program, and Ruminant Livestock Methane Program.

The Global Programs Division (GPD) works in part to implement programs to protect the stratospheric ozone layer. The Ozone Layer Protection program focuses on protection of the Earths ozone layer through achieving the phase-out of ozone-depleting substances in accordance with the Montreal Protocol and other international agreements.

Office of Transportation and Air Quality

The Office of Transportation and Air Quality's (OTAQ) mission is to conduct research and develop tools and methodologies applicable to understanding and addressing the role of the transportation sector in environmental management by advancing clean fuels and technology, and working to promote more livable communities. OTAQ, which employs approximately 400 people, is responsible for developing regulations to control air pollution from motor vehicles, engines, and their fuels. Mobile sources include any engine that is used for a purpose that requires free and immediate movement. Examples of mobile sources include cars and light trucks, large trucks and buses, farm and construction equipment, lawn and garden equipment, recreational equipment, marine engines, aircraft, and locomotives. Activities include: characterizing emissions from mobile sources and related fuels; developing programs for their control, including assessment of the status of control technology and in-use vehicle emissions; carrying out a regulatory compliance program, in coordination with the Office of Enforcement and Compliance Assurance, to ensure adherence of mobile sources to standards; defining requirements for assisting state agency's in implementing State Motor Vehicle Emissions Inspection and Maintenance Programs; and implementing programs for the integration of clean-fueled vehicles into the market.

Office of Radiation and Indoor Air

The mission of the Office of Radiation and Indoor Air (ORIA) is to protect the public and the environment from the risks of radiation and indoor air pollution. The ORIA develops protection criteria, standards, and policies to limit the risks from exposure to indoor air pollutants. ORIA directs a radiation-monitoring program; responds to radiological emergencies; and applies laboratory and research capabilities to evaluate and assess the overall risk and impact of radiation and indoor air pollution. The ORIA is U.S. EPA's lead office for intra- and inter-agency activities coordinated through the Committee for Indoor Air Quality. The ORIA disseminates information and works with state and local governments, industry and professional groups, and citizens to promote actions to reduce exposures to harmful levels of radiation and indoor air pollutants, including asbestos and radon.

Other U.S. EPA Offices and Laboratories

The functions of OAQPS are coordinated closely with those of the Office of Research and Development (ORD), and the Office of Enforcement and Compliance Assurance (OECA). ORD assists all of the program offices of U.S. EPA by assessing new research on health effects, physical and chemical issues relevant to pollution formation and transport and technology developments for mitigation of pollutants. Three particular components of ORD support air quality management programs discussed in this section. The National Center for Environmental Assessment has responsibilities for assessing all new and emerging health effects studies to determine if the new research suggests a need for changing or adding pollutants to the list of NAAQS and or HAP pollutants. The CAA requires a review of the health effects information relative to NAAQS pollutants every five years with an assessment report that describes the basis for decisions about NAAQS revisions. The five-year assessment report is required even if the decision is to keep the NAAQS at their current status. The National Risk Management Research Laboratory has general responsibilities for evaluating new approaches and technologies for assessing and mitigating risks associated with pollution. The Air Pollution Prevention and Control Division has primary responsibility for assisting OAQPS with research and technical support related to air quality management programs. The Atmospheric Modeling Division within the National Exposure Research Laboratory develops, evaluates and supports the various new and existing computer-based modeling systems that are so valuable for simulating air pollution events. These models are used to predict exposure and community risk to new sources, evaluate urban and regional effects of air pollutants, and to simulate control strategies to determine their likely effectiveness.

d. Operational Function of the Organization

The purpose of this section is to describe in general terms how high-level policy decisions are implemented through major programs and individual projects to collectively make progress toward achieving the national goals. The allocation and distribution of a budget is an important part of the operational functions of U.S. EPA. The process that is used to allocate funds to individual programs and projects is also briefly discussed.

Setting Policy Objectives

The planning process has both long-term components that address major environmental and risk issues on the national and global scale, and an annual component that distributes the annual budget to accomplish specific objectives. The U.S. EPA administrator, assistant administrators, and deputy administrators work to set the overall policy objectives for the agency on both the long-term and annual cycles. Decisions are guided to a large degree by technical input provided by managers at the program level, who in turn seek advice and input from the scientists and engineers who have the direct responsibilities for implementing programs.

This planning process also includes the development of budget requests that represent the best estimates of the cost to achieve specific objectives. The administrator then submits the budget request to the President and Congress. Based largely on that input, the President includes a specific budget request for U.S. EPA and other environmental related programs to the Congress. In the United States, Congress has the ultimate authority for establishing the budget of all government agencies, including U.S. EPA.

Once the budget is passed and the agency funding is appropriated, the senior management again meet to decide how to allocate that budget to fund the agency and its personnel, the programs of the individual program offices, and grants to state, tribal and local agencies to assist those agencies in implementing essential components of the policy. In turn Directors of the various program offices meet with the managers of the various organizational components in that program office to allocate funding to those levels. Ultimately, individual operational groups meet to make decisions about how to apply their allocated funding levels to the highest priority projects in each annual cycle.

The 2003 U.S. EPA budget is U.S. $7.7 billion (RMB 63.5 billion). Of that total approximately $1.7 billion (RMB 14 billion) is for employee payroll, building construction and maintenance and other infrastructure needs. Another $1.4 billion (RMB 11.5 billion) is directed to special funds to cover costs associated with the clean up of abandoned locations that are contaminated with hazardous waste, the costs associated with cleaning up contaminated areas at former military sites that are being converted to other purposes and assistance to correct and clean up contamination caused by leaking underground storage tanks. The remaining budget, totaling approximately $4.6 billion (RMB 38 billion) is directed to implementation of programs through grants to state, tribal and local agencies ($3.5 billion, RMB 29 billion), and to fund Universities and other experts at private contracting companies to accomplish specific goals.

For 2003, U.S. EPA management identified 10 priority objectives. These objectives are listed in Table II-7, with the approximate allocation of program implementation funds (in millions of dollars).

Table II-7. Approximate Allocation of Extramural Funding by Objective

Program Objective	Allocated Funds	Percent
Clean Air	$ 598	13
Clean and Safe Water	$ 215	5
Safe Food	$ 110	2
Preventing Pollution and Reducing Risk in Communities, Homes, Workplaces and Ecosystems	$ 327	7
Better Waste Management, Restoration of Contaminated Sites, and Emergency Response	$1,711	37
Reduction of Global and Cross Border Environmental Risks	$ 270	6
Quality Environmental Information	$ 199	4
Sound Science, Improved Understanding of Environmental Risk, and Greater Innovation to Address Environmental Problems	$ 328	7
A Credible Deterrent to Pollution and Greater Compliance with the Law	$ 402	9
Effective Management	$ 461	10

Implementing Projects

Once the policy objectives are established and the budget is allocated at the macro scale described in Table II-7, individual program offices begin the process of defining the allocation of their share of the budget to the individual groups that are charged with completing projects. Each group meets to discuss their proposed list of projects and to select those particular projects that can be completed with the available budget and best achieve the overall policy objectives established for the agency. Management staff at levels of office director, such as the Office of Air Quality Planning and Standards, and the Office of Transportation and Air Quality will coordinate to ensure that programs completed in the individual offices are complimentary and will achieve progress efficiently toward the larger goals.

EPA staff members complete some of the projects directly, while others are completed with assistance from organizations outside the agency. Examples of outside organizations that provide project assistance are laboratories, universities, other government agencies, and private firms. U.S. EPA will also collaborate with other groups interested in evaluating issues related to the implementation of environmental programs. In this way, U.S. EPA can access experts with specific knowledge of certain programs and benefit from collaborating with scientists and engineers who can bring different perspectives to individual activities.

In general, the list of available outside organizations that U.S. EPA staff can access to support these projects have been selected as a result of a competitive process, in which the firms describe their experience, personnel skills and ideas for completing the requirements of the project. This competitive process also includes information on the cost of those services. U.S. EPA then will select that single offer that represents the best value to the overall program. An U.S. EPA staff member will manage the effort to ensure that the products developed and reports achieve the objectives, and are provided within the approved schedule.

Tracking Accountability and Monitoring Progress

The implementation of environmental management programs in general and air quality management programs in particular have grown in the United States over the years and represent an investment of significant amounts of the tax payers' money. It has become necessary to monitor the use of those funds to ensure that progress is achieved and that the overall goals are being addressed. The 1993 *Government Performance and Results Act (GPRA)* was passed to help in this effort. GPRA requires agencies to develop plans for what they intend to accomplish, measure how well they are doing, make appropriate decisions based on the information they have gathered, and communicate information about their performance to Congress and to the public. For example, U.S. EPA's current Strategic Plan established the 10 goals listed in Table II-7, to achieve the overall environmental results that U.S. EPA is working to attain. Each of these goals is supported by a series of objectives that identify, as precisely as possible, what environmental outcomes or results the Agency seeks to achieve within a defined time frame using resources that are reasonably expected to be available.

In the case of the air quality strategic goal, one of the objectives is to have all areas achieve compliance with the national air quality standards by definite dates. This provides a specific goal against which progress can be measured. All of the specific activities and projects completed by the air program are then monitored to provide evidence that progress is being achieved relative to that goal. The continuous monitoring and reporting of progress provides all of the people involved with a clear understanding of what is working, and in some cases, what is not working. This is a valuable tool that helps managers make decisions about changing the implementation strategy at critical times to increase the efficiency of the overall process.

EPA implements this program through a process called "Managing for Results". This approach helps U.S. EPA focus on "outcomes"—actual environmental results such as cleaner air—rather than on more process-oriented "outputs" such as numbers of permits written or industries inspected. In managing for results, U.S. EPA sets a strategic course, and develops and implements plans that meet the available budget constraints to achieve environmental results. The process includes measures of the progress at scheduled times to see if the programs are really working to accomplish what was intended. Finally, adjustments in the plans are made to improve performance if necessary.

B. STATE AND LOCAL ACTIVITIES IN THE UNITED STATES

Examples of air quality management activities at local levels in the United States are discussed in this section. Although many of the specific control strategies discussed here have evolved through the 30 year history of air quality management and air pollution control programs that have been implemented throughout the U.S., the underlying approach can serve as a guideline for cooperation between federal and local agencies in China. New York City serves as the primary example, since New York City and Shanghai share common traits. Some highlights of the air quality management program in Los Angeles are also summarized. The specific experience of Los Angeles, as a leader and innovator in achieving progress to address severe air quality problems, is discussed as an example of how Shanghai could serve in a similar leadership role in China.

1. NEW YORK CITY

a. Air Quality Status

New York City represents a rather unique situation concerning air quality planning. The city itself is a major global center for financial institutions and service industries, and does not have a high concentration of heavy industry relative to its population. Areas of New Jersey to the immediate west of the city, however, are home to several chemical and petrochemical industries, electric generating units, freight and passenger rail facilities, and an active port with its associated air pollution sources. The city is also part of an extensive highly urbanized corridor that spans the eastern seaboard region from Washington, DC to Boston, Massachusetts. The entire area is characterized by high population density, significant industrial production, and an active, and growing transportation corridor.

The city is comprised of five boroughs covering 829 square kilometers (km^2) or 321 square miles. The citywide population, as of April 1, 2000, was 8,008,278, yielding an average population density of 9,675/km^2 (approximately 25,000/$mile^2$). New York City experiences air pollution concentrations at levels above the air quality standard for ozone, and will be subject to control requirements associated with the long term, 8-hour ozone and $PM_{2.5}$ air quality standards. Over the past few years there have been no measurements of PM_{10} at levels above the air quality standards. The air quality in New York City is influenced by upwind emissions sources from other states, and sources in the city affect air quality in downwind areas in other states. The issue of interstate transport of air pollution is being addressed through the coordinated efforts of the states in that region, including New York State, managed by a separate organization known as the Ozone Transport Commission (OTC).

The climate is typical of Northern Hemisphere mid-latitudes. While temperature extremes are modified somewhat by the city's proximity to the North Atlantic Ocean, temperatures vary considerably with season. The summers are quite warm, with average high temperatures in July, the warmest month, of 29 °C (85.2 °F). Throughout the summer months, high relative humidity makes it feel warmer. January is the coldest month with an average high temperature of 3 °C (37.6 °F), and an average low temperature of –3 °C (25.4 °F). Snowfall is measured between November and April. Precipitation is fairly constant through the year averaging between 8.9 and 11.4 centimeters (3.5 and 4.5 inches) of precipitation per month. Prevailing winds are from the west – southwest, although northwest winds frequently accompany winter storms. Nearly all storms moving west to east over the continent influence New York City to some extent. The frequent passage of storm systems results in the movement of air through the city and limits the opportunities for air masses to settle over the area. Stagnation conditions do occur, however, when large high-pressure systems stall on the eastern seaboard. Under these systems air pollutants can build up over a period of 2 to 5 days, creating the worst air quality situations. At times the city is subject to a sea or land breeze that can also circulate air pollutants back into the city causing elevated air pollutant concentrations.

b. Recent Air Quality Trends for PM_{10}, SO_2, and Ozone

Over the past 10 years, concentrations of PM_{10} have been consistently below the annual air quality standard at all monitoring sites in New York City. The maximum observed 24-hour concentrations of PM_{10} in 2003 were consistently about one-third of the national standard. Like all big congested cities there is a significant amount of dust deposited to the streets and buildings. New York has implemented a comprehensive street sweeping program to limit the opportunities for this dust to be suspended into the air. Parking restrictions are active during certain hours of prescribed days to ensure that the street sweepers have access to the street. Parking fines are expensive, $90 (RMB 750) to $150 (RMB 1200)per violation, to encourage people to move their cars during the times designated for street sweeping.

There have been no observed concentrations of SO_2 at, or even close, to the levels of the national standards for the past 10 years. This is primarily due to the fact that there are few significant stationary combustion sources and nearly all of the combustion sources in the city burn natural gas.

Ozone concentrations have been declining in general over the past 10 years although monitors in the city still measure maximum concentrations that are in excess of the level of the national standards. Much of the improvement in ozone concentrations has resulted from emissions standards and control measures applicable to mobile sources, the effort of the OTC to reduce emissions of ozone precursors throughout the multi-state OTC region, and the use of products with lower organic solvent content.

c. Emissions Sources in New York City

Clearly, significant efforts have been made, over the past several decades, to reduce the contributions of stationary sources to the overall air pollution emissions load in New York City. Large fuel combustion sources associated with manufacturing and other industrial activities, in the early 1900s, created dense smoke and high concentrations of SO_2 and other gaseous combustion products. Most heavy industry has relocated to other areas. There are very few remaining coal, wood or residual oil-fired boilers in or near the city. In addition to the air quality benefits, the relocation of large industrial sources is also linked to economic reasons. The cost of land, taxes, and labor are so high in the city that industrial operations are simply not attractive from an operating cost perspective. Most of the business in the city is related to services, including financial services, insurance companies, trade and import/export services, retail, food services, other hospitality services, entertainment industries, and health care facilities. The most significant stationary sources in the city are a few medium-sized, natural gas-fired power plants and boilers at major hospitals, universities, and other commercial ventures.

Area sources and mobile sources contribute the majority of air pollution emissions. Significant area sources include major construction activities that are always present, space heating and water heating, dry cleaners, printing and other surface coating operations, food preparation activities, and a host of other commercial enterprises. Statistics from the most recent national census reveal that natural gas or refined heating oil is used in almost ninety percent of residences for space and water heating. (U.S. Census, 2003a) Since commercial activities are collocated with residential units, it can be assumed that commercial fuel use follows a similar distribution.

Mobile sources include personal automobiles, a large taxi fleet, and other government and commercial fleet operations. Almost all products are delivered to New York from other nearby production and distribution centers. The deliveries are made with medium to large trucks creating a significant amount of traffic from these types of vehicles. The harbor is a major port that includes freight, passenger, and military shipping activities both in New York City itself and in facilities on the west side of the harbor and the Hudson River in New Jersey. There are many water taxis and ferries operating in and around the New York Harbor. The city is served by three major airports: La Guardia in the Northern part of Queens, John F. Kennedy International Airport at the Southeastern edge of Queens, and Newark International Airport outside Newark, New Jersey just to the west of the city.

Public transit systems are a major component of the transportation system in New York City. The subway system is extensive and provides convenient access to almost all sectors of the five boroughs. The bus system is also well developed and the majority of residents rely on the combination of subway, bus, and taxi services in lieu of owning a personal automobile. Over all only 46% of the residents of the five boroughs own a personal vehicle. In Manhattan only 23% of residents own a vehicle. (U.S. Census, 2003b) A significant number of people commute from nearby residential areas north of the city in Westchester County, east of the city in Nassau County, west of the city in northern New Jersey, and even as far away as southwest Connecticut. A large percentage of these commuters also use public transit. Rail and subway systems carry much of the commuter traffic. Within the city, these conveyances are electric powered. New York City itself is not a major rail freight handling area, however, the area just to the west of the city in New Jersey is a major rail freight center.

Annual emissions totals for the five boroughs of New York City for 1999 are presented in Table II-8. (U.S. EPA, 2001b) The relatively small fraction of emissions from point sources reflects the nature of New York City's service-based economy. Highway mobile sources contribute approximately 73% of CO emissions, 54% of NO_x emissions and 35% of VOC emissions. Highway mobile sources also represent approximately 70% of the overall hazardous air pollutant emissions.

Table II-8. Annual Emissions Summary By Emissions Sector For New York City (units are short tons per year)

Emissions Sector	SO_2	PM_{10}	NO_x	VOC	CO
Point	11,231.2	2,118.2	28,085.1	1,321.5	6,769.1
Area	49,641.7	49,205.5	21,250.7	113,216.9	36,827.7
Highway Mobile	4,078.0	2,786.4(1)	100,426.3	72,550.3(2)	894,208.2
Non Road Mobile	3,879.2	2,972.3	35,178.6	18,312.3	290,454.1

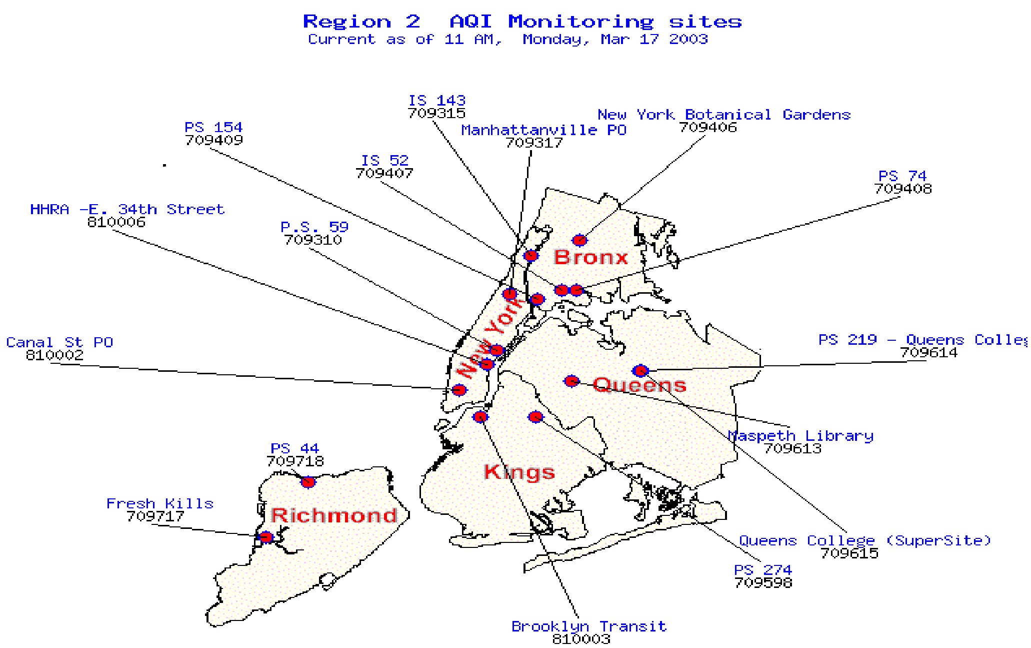
(1) PM_{10} emissions include tire wear, brake wear and exhaust
(2) VOC emissions include evaporative losses and exhaust

d. Monitoring In a High Density Urban Area

The primary purposes of air quality monitoring networks are to monitor population exposure to harmful air pollutants, to identify serious or episodic events, and to document improvements as a result of management programs. The permanent air quality monitoring site locations in the New York City monitoring network are shown in Figure II-13.

The important features of the network for application to Shanghai are the location of the sites in high-density residential areas, and at public schools, colleges, public libraries, and post offices. The obvious advantage of locating monitors at schools and post office sites is that those stations represent the areas where sensitive members of the population are likely to be found. A less obvious advantage is the availability of open space associated with athletic fields at the schools, and parks that are frequently located near main libraries and some post offices in New York City. These open spaces allow the collection of samples that are not unduly influenced by nearby street traffic or channeling of winds down major streets in response to the urban canyon effect. Three of the monitoring sites (those with site identification codes starting with 8) have been established primarily to monitor the effects of traffic in high congestion areas. The Brooklyn Transit site is in downtown Brooklyn near the entrance and exit from the Brooklyn Bridge. The E. 34th Street site is located where the entry collectors to the east bound midtown tunnel meet. The Canal Street location represents one of the primary cross-town routes connecting the Holland Tunnel on the West side of Manhattan to the Williamsburg, Manhattan and Brooklyn Bridges on the East side of Manhattan.

Figure II-13. Air Quality Monitoring Network in New York City



Source: (NYSDEC, 2004a)

The primary objective of a network design like that employed in New York City is to measure peak concentrations of locally generated pollutants. This type of strategy is useful for air quality problems such as SO_2, PM_{10}, and carbon monoxide. New York also has a serious ozone air quality problem, but the ozone problem is more regional in nature and ozone is measured routinely at only three of the network sites in the city. The ozone monitoring sites are in open areas including the Botanical Gardens in the Bronx, a College campus in Queens, and a public school in an area of the Bronx that is less densely populated than most parts of Manhattan. A list of the specific pollutants monitored at each station in the New York City monitoring network is shown in Table II-9.

Table II-9. Pollutants Monitored in New York City Ambient Monitoring Network

Monitoring Site	O_3	SO_2	$PM_{2.5}$	CO	Monitoring Site	O_3	SO_2	$PM_{2.5}$	CO
709310 public school		✔		✔	709613 library			✔	
709315 public school			✔		709614** college			✔	
709317 post office			✔		709615** college	✔	✔		✔
709406 public garden	✔	✔		✔	709717 landfill			✔	
709407* public school	✔	✔	✔		709718 public shool			✔	
709408 public school			✔		810002 post office			✔	
709598 public school			✔		810003 traffic density				✔
709609 post office		✔			810006 traffic density				✔

* This site also monitors PM-10 although New York City is in attainment for PM-10

** These sites are included in the PM super site monitoring program

With the exception of source area monitoring sites, monitoring priorities should be similar in Shanghai. A permanent ambient monitoring network with a similar distribution that allows each station access to an open area around the sample intake, and a consistent, reliable source of power would provide a wealth of information on existing population exposures and future trends in reducing those exposures in response to further air quality control programs. Since Shanghai includes industrial areas with concentrated air pollution sources, the network design in Shanghai needs to include specific sites near these industrial centers, to ensure that the network is capable of tracking trends in releases from these areas, and to identify episodes that might have health consequences to the surrounding populations.

The monitoring sites collocated at the Queens College (709614 and 709615) are part of the PM super site program. U.S. EPA initiated the super site program soon after it promulgated the air quality standard for $PM_{2.5}$. Although ambient measurements of $PM_{2.5}$ and smaller size fractions had been collected and analyzed in specialty studies, there was no reference method or monitoring procedure that could be applied to the required ambient monitoring network that would ensure overall consistency and comparability of the ambient measurements. U.S. EPA awarded a series of grants to fund the operation of these super sites to gather information to study instrument comparison, and to provide information that could be used to address a host of scientific and policy questions. For example, the primary goals of the New York City super site are to track the trend response of $PM_{2.5}$, and the elemental and organic components of $PM_{2.5}$, to trends in relevant emission rates, and to establish the links between secondary $PM_{2.5}$ formation and ozone formation.

Similar types of studies conducted in Shanghai could provide a valuable dataset to address broader issues and decisions about progressive stages of control strategy implementation that would also have significant implications for many other areas of China. For example, Shanghai air quality monitoring data show a significant seasonal variability in NO_2 and TSP for monitors located in the urban core and for the city as a whole. A series of research programs similar in nature to the super site program could be designed to investigate the reasons for this variability and the consequences of those conditions on mitigation policy. Additional information about the New York City ambient monitoring data and network design can be found at the New York State Department of Environmental Conservation Internet site. (NYSDEC, 2004b)

e. Air Quality Modeling

During the development of SIPs for PM_{10} and CO, dispersion models were used to simulate the high concentration areas immediately downwind of hot spots for those pollutants. In New York City, mobile sources and areas of high traffic congestion were the dominant hot spots. The use of dispersion models helped planners improve traffic flow through a series of transportation control measures. Use of alternating one-way streets and avenues, traffic light timing, and dedicated turning lanes are examples of these transportation control measures. Dispersion models can be used to simulate the emissions patterns that are anticipated to result when these control measures are put into effect to facilitate the adoption of appropriate measures that achieve the desired air quality benefits without creating unnecessary traffic congestion in other locations. Currently, dispersion models are used to study the impacts of new development to ensure that expected traffic and other new sources associated with the development do not cause violations of the standards.

Ozone and $PM_{2.5}$ pollution in New York City is influenced significantly by regional source activities, as well as sources within the city. NO_x transported from power plants in upwind states as far away as Ohio and Tennessee contribute to ozone and $PM_{2.5}$ formation that affects New York City. Regional air quality models are used to evaluate these regional air quality problems. New York is part of the ozone transport commission (OTC), and participated in the ozone transport assessment group (OTAG). These organizations are cooperative efforts among several states and the U.S. EPA. One component of these regional programs involves the application of regional modeling that represents the emissions of all sources in a large region. The OTAG addressed the ozone transport phenomenon in the Northeast United States, and included all of the states from Michigan in the West to North Carolina in the South.

The regional models are used to simulate the air pollution emissions that are expected in future years given all of the national and state-level control programs and with appropriate assumptions about population and economic growth. Various additional emissions control scenarios are simulated to determine the best regional control strategy that achieves the desired air quality benefits within an acceptable implementation cost limit. For example, the OTAG process identified a series of large stationary combustion sources throughout the region and assigned NO_x emissions reduction targets for each state in the region. Similar regional modeling has been used in the past to identify appropriate regional controls associated with acid deposition in New York State, and will be used to assist in the formulation of the New York SIPs for the 8-hour ozone standard, the $PM_{2.5}$ standard and regional haze mitigation programs. The Bureau of Air Research, within the New York State Department of Environmental Conservation has sophisticated modeling capabilities that are applied to support both urban and regional scale planning studies.

f. Air Quality Controls Identification and Policy Development

In the early 1900s, New York City was a major manufacturing center. The manufacturing sector thrived because all of the conditions needed to support a manufacturing based economy were available. The transportation network of trains and shipping was well developed to facilitate the movement of both raw materials and finished products. There was also a large population of available labor. The city became a major center for the manufacture of clothing, shoes, heavy equipment, and other commodities. Many of these facilities operated a coal-fired boiler and control programs were minimal. Over time many of these manufacturing industries moved to other locations for economic and environmental reasons. As the heavy industry relocated to outlying areas, the overall air quality in New York City improved. Mobile sources and the small stationary sources that are included in the area source sector have replaced industrial sources as the dominant air pollution source sector in New York City. Most of the specific control activities within New York City, therefore, attempt to reduce the air pollution from these mobile and area sources.

A series of initiatives have been introduced throughout the 1990s to promote the use of alternative fueled vehicles in New York City. (NYSERDA, 2004) The State of New York started a program to require 75% of new vehicles purchased for State owned vehicle fleets to be alternative fueled vehicles by 2001. That program was expanded in 2001 to require 100% of all new light-duty vehicles purchased by State agencies to be cleaned fueled vehicles by 2010. Several agencies and school systems in New York City have joined in an effort to convert the city bus service to clean fueled technologies.

Approximately 35% of the mobile source emissions in New York City result from the fleet of 12,187 licensed taxicabs. The New York City Clean Fuel Taxi program is being implemented to encourage the conversion of the taxi fleet to clean fueled vehicles. The program creates incentives for the taxi companies to convert to natural gas fueled vehicles and provides grants to establish natural gas refueling sites to support the increasing numbers of natural gas fueled taxis. The initial phase of the program resulted in 300 natural gas fueled taxis operating in the city. The city has authorized the issue of an additional 900 taxi licenses between 2004 and 2006 but also requires 9% of the new vehicles to be natural gas fueled or to use a hybrid electric engine.

A key feature of mobile source control programs in all areas of the United States subject to the ozone air quality standards is the inspection and maintenance (I&M) program. All new cars sold in the United States are subject to exhaust emissions standards. California adopted a set of exhaust emissions standards that are more stringent than the national standards to achieve even more emissions reduction of the pollutants that form ground level ozone. Starting in 1999, New York State also adopted the California emissions standards partially because of the large contribution of mobile sources to air pollutant emissions totals in urban areas of the state. While new cars are certified as meeting these standards before they can be offered for sale, the control equipment can deteriorate over time. Studies of in-use vehicles have revealed that 5% of the cars tested cause more pollution than the other 95% combined. (SN Monthly, 1998) The I&M program requires that all registered vehicles be tested on a regular schedule to verify that the pollution control systems are operating correctly. These I&M programs can catch the small percentage of cars that are causing the most emissions, and they are required in all areas subject to the ozone air quality standard.

The I&M program in New York State, is operated by the State Department of Environmental Conservation and the Department of Motor Vehicles. Car repair facilities purchase the equipment used to test the cars, and employees are trained to perform the tests following a specified procedure. Individuals can then take their car to one of these authorized facilities to have the test completed. There are 4,028 licensed test facilities in the New York metropolitan area. Vehicles that pass the test are given a sticker that is displayed on the windshield. The owner of any car that fails the I&M test has to have the car repaired so that it will pass the test. The driver can receive a waiver that will allow the car to be used when a repair facility verifies that at least $450 (RMB 3700) was spent in an attempt to repair the emissions control system.

All passenger vehicles, including taxicabs and light trucks, are subject to the I&M program. Information on the New York State motor vehicle I&M program can be found at the New York State Department of Motor Vehicles Internet site. (NYSDMV, 2004)

The U.S. EPA recently promulgated emissions standards for heavy-duty diesel engines. (U.S. EPA, 2004i) These standards are applicable to new diesel engines put into service and will be phased in over the next five years. As the fleet of delivery and transport trucks is upgraded, these rules will significantly reduce emissions of $PM_{2.5}$ and exhaust gases. The diesel engine controls use devices that remove the pollutants as the exhaust passes through those devices. Since sulfur impurities in diesel fuel deteriorate the particulate filters, requirements that limit the amount of sulfur in diesel fuel have also been put into force. Together these rules will reduce emissions of SO_2, $PM_{2.5}$, and NO_x.

The regional NO_x controls, initiated in response to the OTAG assessment process, are implemented through a regional NO_x emissions trading program. Each state participating in the program has a NO_x emissions cap that considers the future emissions load from point, area and mobile sources. Each participating state is required to develop and implement a SIP to achieve the targeted emissions limits. Since the objective of this NO_x regional control program is to reduce the regional ozone concentrations in summer months, the limits are only applicable in the summer. One approach to achieving the limits is to reschedule certain fuel burning operations that have higher NO_x emissions potential to other times of the year.

Following mobile sources, area sources remain a large sector of emissions of SO_2, PM_{10} and VOCs in New York City. Much of the area source emissions of SO_2 and PM are caused by the large number of small combustion sources used in commercial operations and for residential space and water heating. As energy demand increases, these sources will inevitably increase. Newer, more energy efficient technologies and alternative energy generating units have the potential to significantly slow the rate of increase in emissions in response to the increase in energy demand. There are several programs operated both by the State of New York and New York City to encourage the use of high efficiency products and to address conditions that waste energy.

As the overall electricity demand increases in New York City, additional generating capacity is needed to provide a consistent base load and to meet peak demand conditions. Since 2000, the New York Power Authority (NYPA) has installed 6 small power plants (SPP) to meet the increased energy demand in lieu of siting and installing larger generating units. These SPP units are simple-cycle gas turbine generators, equipped with selective catalytic reduction systems to control NO_x emissions. Overall these units have achieved lower emission rates for CO, NO_x, CO_2, PM, SO_2 and VOCs during steady state operations than the other power generating facilities in the city. The NYPA is working on improved operating practices to reduce the emissions load during periods of start up and shut down. (NYPA, 2004) The trend for smaller and cleaner units to meet incremental electric energy demand will continue based on the environmental benefits, and costs associated with this strategy relative to the choice of adding a major new power plant. (NYPA, 2003)

g. Implementation

The New York State Department of Environmental Conservation is the primary agency responsible for developing and managing air quality management programs in New York City. The state agency headquarters is located in Albany, New York, the state's capital city. The Division of Air Resources oversees all aspects of the air quality management programs. The Air Resources Division has 208 full time staff members in the headquarters office, excluding administrative staff. The Air Resources Division coordinates directly with the U.S. EPA to ensure that SIP requirements are achieved and plans conform to the national requirements. The Bureau of Air Quality Planning, consisting of 19 staff members, has primary responsibility for developing the SIPs and monitoring progress toward achieving air quality goals. Many other groups within the Division of Air Resources assist in the air quality management program, including research, program development, permitting, I&M program, monitoring, and compliance functions. The Department also operates regional offices around the state to assist with program development, review and compliance actions. The State Region 2 office is located in New York City and serves only the five boroughs of the city.

The City of New York has independent agencies that are involved in the implementation of environmental policy. The New York City Department of Environmental Protection is a city government agency that implements city specific regulations. The City Department of Environmental Protection is primarily involved in oversight of the drinking water and wastewater management systems in the city. Air pollution responsibilities are focused on identifying sites in need of asbestos removal and regulating the many firms in the city that conduct asbestos remediation projects. A separate agency of Environmental Coordination is operated from the Mayor's office. The Mayor's Office of Environmental Coordination assists other city agencies to ensure that all activities within the city are in compliance with state and federal environmental regulations and laws. All city programs and projects are subject to an environmental assessment process to identify and mitigate, to the extent possible, any negative environmental consequences of city projects. The city agencies coordinate with the State Region 2 staff on issues related to the air quality planning process when necessary.

h. Evaluation of Effectiveness and Modification of Controls as Necessary

One of the primary uses of ambient air quality monitoring data is to provide a record over time of the condition of the air quality. The data not only identify the locations and times when air quality concentrations approach or exceed the national standards, but they provide a record of how air quality is changing over time. In a city like New York, where new development is continuous, the relationships between air pollution sources and the city's population change over time. Air quality management plans are implemented to achieve a desired result at some time in the future. Therefore, plans depend on estimates of how growth and economic conditions will affect emissions patterns. An important aspect of air quality management then is to continually update the pollutant emissions inventory to determine if the overall emissions are changing like the predictions. At the same time, following the trends in pollutant concentrations allows the planning agencies to verify that the plan is having the intended purpose. Most plans have interim goals and failure to achieve the interim goals provides a signal that more needs to be done to keep on track toward the ultimate final goal. The SIP is an ever evolving and changing document. As new regulations and policies are initiated at the federal level, SIP components to address those new programs are prepared and implemented by the responsible state and local agencies.

2. LOS ANGELES

a. Forcing New Technology and Approaches

Los Angeles is a rapidly growing urban center that has a diverse industrial, transportation and commercial economic base. The air basin surrounding the city of Los Angeles covers 31,000 square kilometers (~12,000 square miles) and extends from a coastline on the west to dry desert like conditions in the Eastern portions of the air basin. It is rimmed on the North, East, and South by mountains that serve to channel airflow from the West to East and to limit dispersion. In addition, the climate is such that sunlight shines brightly on a majority of days. Rainfall and other meteorological events that can cleanse the air of contaminants are infrequent. These conditions are very favorable to the buildup of primary pollutants and the generation of ozone and fine particulate matter, two of the secondary criteria air pollutants that are addressed by the U.S. CAA. The South Coast Air Quality Management District (SCAQMD) was created to oversee air quality management in this region.

Los Angeles is a relatively young city and most of the development and population growth have taken place during the age of the personal automobile. For example, the population of Los Angeles County increased by more than 50% since 1960. The metropolitan area population is approximately 15 million people, creating a population density of approximately 440 per square kilometer (~ 1,250 per square mile). That level of population density was made possible by the widespread use of the personal automobile and is one of the underlying causes of the severe air quality problems that are found in Los Angeles. In 1996 it was estimated that there were 10 million vehicles used for personal transportation in the metropolitan area and the number of cars and miles traveled is expected to increase into the foreseeable future. It is estimated that vehicle traffic will exceed 380 million miles per day by 2010.

Los Angeles, as well as other cities in California, started to experience serious air quality events and began to implement programs to address the health effects associated with air pollutants before many other areas of the United States. Ozone concentrations in excess of 0.6 ppm, five times the level of the current air quality standard, were observed in Los Angeles in the 1950s and 1960s, well before air quality was addressed in a meaningful way by any federal agencies. At those concentrations, even healthy people experience difficulty in breathing and tearing of their eyes. The situation required action, and as a result the area began its history of being at the forefront of regulation and innovation in addressing air quality management.

Some of the first actions taken in Los Angeles involved restrictions on activities that were the obvious sources of visible smoke. Outdoor burning of residential trash was banned, and readily available controls for smoke and SO_2 were mandated for the large combustion sources. While these activities did reduce the direct emissions of smoke and SO_2 the conditions resulting in most of the health effects were still observed and it became obvious that other pollutants were responsible for those health effects. The serious efforts to understand the causes of the air pollution problems and to identify necessary steps to control the pollution began in Los Angeles in the 1950s. The research quickly led to a set of conclusions that implicated NO_x emissions from automobiles and other combustion sources along with evaporative losses of organic compounds from liquid fuels storage and distribution as the culprits. Ozone formed as a secondary pollutant was identified as the primary cause of the health related outcomes and the modern era of air quality management based on the control of precursors that contribute to secondary air pollutants began.

The conditions and history associated with Los Angeles make it an interesting case study in how air quality programs are developed and implemented. Los Angeles, and more generally, the State of California also provide case studies in how one region with extraordinary environmental conditions can serve as a leader to force regulatory programs and innovative approaches to reduce the negative effects of pollution. In response to these problems a State Agency called the Air Resources Board (ARB) and a local agency called the South Coast Air Quality Management District (SCAQMD) were created specifically to address air quality management issues. Today the California State ARB employs a staff of more than 1,000 scientists and engineers, and administers a budget of more than $100 million (RMB 825 million). Similarly, the local South Coast agency employs 750 people, and has a budget of approximately $95 million, or RMB 78 million (Hogo, 2004).

Clearly, the combination of regulatory approaches, economic incentive programs and innovative voluntary strategies to reduce air pollutants has been highly successful in the Los Angeles air basin. Air quality monitoring data show that downward trends in ozone and PM_{10}, the pollutants of most concern in Los Angeles, have been occurring over the past decade. One hour average ozone concentrations have declined steadily since 1980. Specifically, the maximum one hour average ozone concentration reported in the Los Angeles planning area in 1980 was 0.430 ppm. The maximum concentration recorded in 2003 was 0.194 ppm. Concentrations based on the new 8-hour NAAQS have declined from 0.336 ppm to 0.153 ppm during the same time period. PM_{10} concentrations have experienced similar improvement. The maximum 24-hour average PM_{10} concentration of 649 $\mu g/m^3$ in 1992 has been reduced to 164 $\mu g/m^3$ in 2003, and annual average PM_{10} concentrations declined from 94.5 $\mu g/m^3$ in 1988 to 56.1 $\mu g/m^3$ in 2003.

While the region has benefited from emissions standards and other control programs initiated on the national-level, the State of California and the SCAQMD have gone far beyond national-level pollution mitigation strategies to achieve deeper cuts in air pollutant emissions than have been achieved in other parts of the country. No two areas are identical in terms of the mix and distribution of the sources of air pollutants, and areas are subject to different meteorological influences that contribute to air quality problems. The experience of the Los Angeles area demonstrates how a strong cooperative effort involving national, state and local programs is the most efficient way to achieve timely progress in improving air quality.

The examples of actions taken in the Los Angeles area in the 1990s to achieve progress toward air quality goals demonstrate the necessity of the combined national, state-level, and local-level approach. Details of the specific actions taken by the SCAQMD to address air quality management can be found at the SCAQMD Internet site. (SCAQMD, 2004) Selected programs adopted by the SCAQMD are listed below:

- Natural gas and other fossil fuels with low sulfur concentrations make up almost all of the local combustion based electric generating capacity. This approach reduces SO_2 emissions and other hazardous air pollutants associated with coal and oil combustion;
- The Los Angeles area recognized the relative importance of vehicle traffic to total emissions load in the 1950s. In response, California has adopted tailpipe emissions standards for highway passenger vehicles that are stricter than those applied in the rest of the country. That trend continues in the present;

- California and Los Angeles have led the nation in identifying and implementing control programs to limit the solvent content of a variety of products. Examples of products that are subject to strict organic solvent content include industrial surface coatings, architectural surface coatings, adhesives, consumer products, metal finishing processes, auto repair and body shops, and paints used to mark traffic lanes and other traffic control markings on road surfaces;
- The SCAQMD, in coordination with the State of California agencies, researched the role of evaporative emissions from gasoline-fueled, mobile sources and pioneered the development of technology using fuel-quality based approaches to reduce the quantity of organic compounds emitted by evaporative process from cars and light trucks during routine operations;
- The area also initiated systems to collect and recycle headspace vapor during fuel transfer processes associated with filling underground tanks at vehicle refueling facilities and in filling the gasoline tank in individual cars;
- The area has been actively in the forefront of identifying the contributions of off-road mobile source equipment (e.g., tractors, ships, trains, construction equipment, and lawn care equipment, etc.) to the total air pollution load and to develop improved engines and control devices for this type of equipment;
- Los Angeles has implemented programs that require certain organizations with large fleets of vehicles to convert part or all of the fleet to low emitting vehicle (LEV) technology, and alternative propulsion technology that approaches zero emitting vehicle (ZEV) technology. The area is also investing in research toward the development of vehicles powered by fuel cell technology that can match the performance and range of typical gasoline powered engines;
- Los Angeles has also been a leader in promoting the conversion of high emitting, heavy-duty diesel engines (e.g., urban transit buses, trucks used in long-haul freight transfers) to newer, cleaner engine technology; and
- The SCAQMD has also pioneered public relations strategies and programs in the schools that are intended to explain the contributions that individuals make to air pollution and to provide information on simple things people can do to reduce emissions.

Despite the impressive history of progress, air pollution concentrations in Los Angeles remain above the level of the 1-hour ozone and 24-hour PM_{10} air quality standards. Although the Los Angeles agencies have developed a plan to achieve compliance with the 1-hour ozone and 24-hour PM_{10} standards more controls and will be required to comply with the new 8-hour ozone and $PM_{2.5}$ air quality standards. Further controls are not easy, however, and the area continues to explore innovative ways to encourage even more control from mobile and stationary sources. As the typical regulation based approaches for air pollution control are implemented, the incremental cost of controls subject to further command and control type regulatory programs become economically unattractive. For example, in the Los Angeles basin planning process, any control option that costs more than $5,300 (RMB 44,000) per ton of PM_{10} controlled, is considered to be economically prohibitive, and implementation would be delayed pending the identification of other less expensive options.

The SCAQMD has adopted several specific innovative approaches to achieve further emissions reductions, partially in response to the rising incremental costs of further regulatory control techniques. One approach is the expansion of an emissions trading market known as the Regional Clean Air Incentives Market (RECLAIM) that allows inter-sector trading of emissions credits. The RECLAIM program allows companies to offset emissions reductions targeted for mobile sources by reducing emissions from stationary sources, or buying credits for excess emissions reductions achieved by other companies in any sector. The new program known as the Intercredit Trading Program that expands the number of entities that can participate in the trading, establishes a schedule for trade amounts that accounts for the inherent uncertainty of emissions estimates for mobile and area sources, and considers air quality benefits associated with shifting emissions from one season to another to reduce the air quality impacts of the emissions. Another program associated with the Intercredit Trading Program is the Air Quality Investment Program (AQIP). This program allows facilities to meet their emissions reduction requirement by paying money into a fund that is managed by SCAQMD. The funds are applied by SCAQMD to achieve equivalent emissions reductions from other sources in the area. Together, these programs allow individual regulated entities extra flexibility in meeting their requirements while maintaining the desired progress toward targeted region wide emissions limits. These programs apply to all industries and all pollutants.

Although Shanghai does not share all of the geographical, and meteorological conditions that are associated with Los Angeles, there are several factors that are similar to the situation in Los Angeles. Shanghai is in a position to be the leader and model for the rest of China in implementing air quality management approaches. While the examples from the Los Angeles experience may not be directly applicable to the Shanghai urban area at the present time, the concept of developing advanced and innovative approaches to achieve early and measurable air quality results is applicable to Shanghai.

Indeed, the local agency has already established this precedent by requiring the creation of Near Zero Coal Use (NZCU) districts within the city. This program closely mimics the initial actions to promote cleaner fuel choices that were adopted in Los Angeles. Similarly, there are a host of other innovative actions that can be directed to the specific conditions observed in Shanghai, based on the Los Angeles model. Like Los Angeles in the United States, Shanghai is positioned to become the leader in the evaluation, implementation, and demonstration of advanced pollution control activities and serve as a model for the rest of the country.

Specifically, Shanghai is in a position to apply the experience of Los Angeles in the creation and implementation of programs to address the following issues:

- Expand on the Near Zero Coal Use district concept to further reduce the concentrations of sulfur dioxide and particulate matter in the high population areas of the city;
- Begin an effort to measure ambient concentrations of ozone in the summer months to determine if there is a need to address this important health related secondary air pollutant;
- Identify opportunities to encourage local industries that use large quantities of organic solvents to adopt alternate processes that can use raw materials, and intermediate feedstocks with lower organic solvent content;
- Encourage the use of water-based products for industrial and residential surface coating activities whenever possible;
- It is anticipated that the use of the personal automobiles will increase significantly in the near future. As this inevitable change occurs, Shanghai can implement early programs to require tailpipe emissions limits based on existing automobile manufacturing methods, and implement vapor loss controls in the fuel distribution and refueling activities;

- Enhance and improve existing public transportation services to encourage continued use of the transit system. This will be the most effective way to slow the growth of personal automobile use;
- Begin planning studies to define effective transportation control measures that will increase traffic flow and decrease congestion at critical intersections and road segments in the city. In addition, the development of parking restrictions, and parking fee structures and strict enforcement of those provisions can discourage nonessential personal automobile use. These measures will reduce overall emissions from mobile sources and limit the potential for carbon monoxide hot spots;
- Start planning to facilitate the collection of important activity data that will be useful in generating a comprehensive emissions inventory;
- Complete some basic modeling studies to gain insights about the geographical extent of air quality problems resulting from emissions in the greater metropolitan area, and the contributions of areas around Shanghai on air quality in the city; and
- Continue to coordinate with other local governments, regional authorities, and national agencies to ensure a coordinated and comprehensive approach to air quality management.
- Consider a public outreach campaign to inform the citizens of Shanghai about the overall air quality management plan and things that individuals can do in their everyday activities to improve air quality.

SECTION III. COMPARISON OF U.S. AND CHINA AQ MANAGEMENT PROGRAMS

Table III-1 presents a summary comparison of the air quality management approaches and capabilities in the U.S. and China organized according to the basic steps in air quality management as used in the U.S. The final row provides a comparison of the roles of and interaction between the national/federal and the municipal/state levels of government with regard to air quality management.

Table III-1. Comparison of U.S. and China AQ Management Programs

Management Process Step	U.S.	China
Air Quality Goal Setting	• Goals are set at the national level, embodied in the National Ambient Air Quality Standards (NAAQS). • NAAQS cover five primary pollutants (CO, NO_2, SO_2, Pb, PM_{10}) and two secondary pollutants (PM $_{2.5}$, O_3). • NAAQS contain two standards: (1) primary standards for protection of human health; and (2) secondary standards for protection of other environmental/commercial values, which are applied universally in all locations and at all times. • NAAQS are based solely on air pollutant concentration levels believed to protect human health and the environment. Economic cost or technical feasibility are not considered in setting NAAQS. • NAAQS standards and concentration levels are reviewed every five years to determine if new health or welfare effects research results warrant changes in the standards to protect health and welfare. • Regional air quality issues that involve transport of pollutants among states are guided by regional agreements formulated through joint multi-state and U.S. EPA partnerships. Member states of these partnerships agree to develop SIPs that are consistent with the regional objectives. • Specific air pollutants that cause serious health effects, but are limited to a small group of source types, called hazardous air pollutants, are regulated through source specific emissions control requirements. Following the implementation of the best possible technology based controls the remaining risk to public health will be assessed and further control requirements will be identified as necessary to ensure public health protections. • Pollutants that result in annoying odors and noise pollution are treated as nuisance pollutants and are regulated locally. • Indoor air quality is addressed by regulating the content of some consumer products.	• Goals are set at the national level, embodied in the National Ambient Air Quality Standards(GB 3095-1996). • GB 3095-1996 covers eight primary pollutants (CO, NO_2, SO_2, PB, TSP, PM_{10}, F, B[a]P), one secondary pollutant (O_3), and one pollutant class (NO_x). • GB 3095-1996 contains three grades or levels of standards, applicable to (1) pristine areas; (2) residential/commercial areas; and (3) industrial areas (listed in order of decreasing stringency). (The applicable air quality standards are listed in Table 1-7). • While standards for Grade 2 residential areas are set at levels that are protective of public health, implementation programs and progress toward achieving the standards are based on technical and economic attainability at the local level, consistent with the overall 5-year plan objectives.

Table III-1. Comparison of U.S. and China AQ Management Programs

Management Process Step	U.S.	China
Emissions Inventory	• Comprehensive inventories are developed at the State/local/tribal level, in the process of preparing State Implementation Plans (SIPs), the basic planning unit for AQ management in the U.S. • Emissions estimates are developed primarily through the use of emission factors and representative activity data. Activity data for many area sources are based on government surveys. Activity data for other point sources is reported by the facilities and emissions calculations are reviewed and verified by appropriate agencies. Source monitoring data is applied for large stationary sources (e.g., electricity generating units). Mobile source emissions are prepared by using national-level emission factor models and local estimates of vehicle miles traveled. • Inventories address all source types, including stationary, highway mobile, off road mobile, area sources, and biogenic/geogenic sources. Sophisticated estimation and modeling procedures are used to extrapolate emissions from large numbers of small sources. • Economic models are used to project future year inventories. Inventory data are used: • As inputs to sophisticated AQ models (both local dispersion models and regional transport models), as part of AQ management planning and SIP development; • As a means of identifying all main source types to which controls may be applied; • To estimate control costs relative to health and environmental benefits; and • To track the relationship between trends in pollutant emissions and observed air quality over time.	• Data are based largely on unverified responses to government surveys, unverified industrial self-reporting, estimation of emissions based on fuel consumption or other operational data, and some source monitoring. • Data for electric utility point sources are prepared by facility managers primarily by the application of emission factors to fuel consumption data. • Data for other large point sources are typically estimated by the local EPB from estimates of operating data supplied by the facilities. CRAES completes estimates for sources that are not addressed by the local EPBs. • In 1995 a national survey was completed to collect data that could be used to develop emissions estimates for all industrial sources. The database was completed, but remains unverified. • Data for area sources are limited. • There is no national level mobile source inventory. Inventory data are used: • To establish benchmarks against which future interim air quality goals are measured; • As a means of identifying important source categories for possible control measures; • To track changes in emissions magnitude and patterns in response to control measures.

Table III-1. Comparison of U.S. and China AQ Management Programs

Management Process Step	U.S.	China
Monitoring	• Comprehensive nationwide monitoring network for NAAQS pollutants and other regional welfare related pollutants (visibility impairment, acid deposition, etc.). • The network consists of national air monitoring sites (NAMS), state and local air monitoring sites (SLAMS), and special study sites (Clean Air Status and Trends Network [CASTNet], Interagency Monitoring of Protected Visual Environments [IMPROVE]. • Covers wide range of pollutants, including primary and secondary pollutants (O_3, $PM_{2.5}$). Particulate filters are analyzed to quantify the composition of the total particulate matter mass. • Hundreds to over a thousand sites depending on the air quality status of the pollutant. Monitoring is generally concentrated in and around major urban centers. • As air quality goals are achieved and verified through the monitoring network, the number and distribution of sites are altered to allow limited financial and personnel resources to be applied to emerging and more serious needs. Monitoring data are used to: • Identify AQ problem areas and pollutants and populations exposed to unhealthy air pollutant concentrations; • Help to identify sources (in some cases) through filtrate analysis; • Verify AQ models; and • Assess success in meeting AQ goals. Comprehensive nationwide monitoring data readily available via the Internet.	• Monitoring is conducted at over 2,000 stations most of which are operated at county and municipal levels, and coordinated by a national environmental monitoring center. • Technology varies from manual methods, to automated instrumentation. • Municipal monitoring centers cover mainly three pollutants: TSP, SO_2, and NO_x. Some monitoring stations cover a few other pollutants listed in GB 3095-1996. • Secondary pollutant monitoring capability is very limited (few stations), as are the capabilities to regularly analyze components of total particulate mass. • SEPA is coordinating a program to systematically upgrade and modernize monitoring equipment in large cities. Monitoring data are used to: • Identify AQ problem areas and pollutants; and • Assess success in meeting AQ goals. Air quality data published via mass media on a weekly basis and on a daily basis in many of the large cities. Data for Shanghai are available via the Internet.

Table III-1. Comparison of U.S. and China AQ Management Programs

Management Process Step	U.S.	China
Modeling	• Sophisticated modeling required to develop and demonstrate effectiveness of AQ management plans (SIPs). • Urban and regional scale transport and transformation models used, as well as back trajectory and source - receptor models. • Physical transport models may be used, but reactive (photochemical) models must be used in O_3, and $PM_{2.5}$ nonattainment areas, and for regional haze assessments. • Models consider emissions from all important sources (e.g., point, area, highway mobile, off road mobile and biogenic.) • Model output verified with monitoring data. Models used to: • Help identify key sources (back trajectory and source - receptor models); • Establish detailed understanding of the link between emissions from individual source types, ambient air quality, and population exposure levels; • Identify key sources, and select the specific sources to which control measures should be applied; and • Assess the expected effectiveness of alternative control strategies, and select the optimal strategy for achieving AQ goals.	• Use is largely limited to Gaussian physical transport models, and basic models linking total emissions from larger stationary sources to ambient air quality at the municipal (city) scale. Model use not required for establishing AQ management strategies. • Reactive models are currently being developed for Shanghai, possibly other cities. Back trajectory modeling is not applied. Models used to: • Assess the effect of total emissions from larger stationary sources on urban air quality and population exposure.
Controls Identification	• Controls are established at the state level (SIP) in response to federal guidance and requirements, and are a mixture of source category- and pollutant-specific national and regional technology controls, and location-specific, health based controls. Economic incentives are also used, tailored to fit the needs or particular source categories, pollutants, and regions. • Highway mobile and off road mobile source control requirements include measures related to engine performance, exhaust gas and evaporative emissions control devices, and fuel composition requirements and are established nationally. California has adopted mobile source control regulations that are more stringent than the national level requirements. Some individual urban areas have independent requirements for gasoline formulations termed reformulated gasoline (RFG) to address specific local control plans.	• Controls established at both the national level (emission standards, total cap on emissions or total load control) and at the provincial/municipal level, where strategies are developed to achieve national AQ standards. • National agency (SEPA) reviews plans developed by municipalities, but has no authority to step in and impose a SEPA plan if the plan developed by the municipality is inadequate. SEPA cannot compel action at the municipal level except for extreme cases which are brought before the State Council. • Mobile source emissions limits are developed by national agencies. • Specific sources to be controlled, and controls to be applied, are identified largely through an intuitive process. Sources which clearly contribute very substantially to ambient pollutant levels, and for which control measures are deemed economically and technically attainable, are selected for controls.

Table III-1. Comparison of U.S. and China AQ Management Programs

Management Process Step	U.S.	China
Controls Identification (continued)	• Federal agency U.S. EPA) reviews SIPs. If state fails to establish adequate controls the federal government steps in and imposes a control strategy (Federal Implementation Plan or FIP). • Controls identified through a process of detailed emissions inventory, extensive AQ monitoring, and sophisticated modeling. • Sources selected for control based on comparative assessment of the effects of emissions from various sources on AQ. • Complex control strategy developed specifying detailed control technologies or levels for individual source types. • Control strategy tailored to each area by selecting from a large “toolbox” of control measures. • Individual states prepare SIPs to address regional air quality issues that must be compliant with regional agreements that have been developed through the multi-state and U.S. EPA partnerships. • Control requirements are more extensive and stringent in more polluted areas; all areas must meet the same health-based NAAQS. • Stationary source control requirements are codified in a legally enforceable operating permit. The operating permits are included as components of the SIP and are therefore federally enforceable if it is determined that the state has not taken appropriate steps to ensure compliance with approved permit conditions.	• Control measures in some cases specify technological requirements (e.g. requirement for desulphurization at large coal-fired power plants) but generally are not specific (e.g., 10% reduction in the emissions of SO_2). • Control measures are least stringent in the most polluted areas, which are generally deemed industrial zones and subject to the least stringent (Grade 3) AQ standards.

Table III-1. Comparison of U.S. and China AQ Management Programs

Management Process Step	U.S.	China
Implementation	• Federal and state levels of government, industry representatives, and NGOs participate in the development of the implementation strategy, but state governments are responsible for the implementation plan. If the state fails to develop an approved plan or fails to implement its approved plan the federal government will intervene by developing and managing a federal implementation plan (FIP). • Implementation is believed to be comprehensive, with practically all controlled sources "captured" by the implementation process and brought into compliance. • Implementation measures include source specific emission limitation regulations, product content regulations, mobile source engine and fuel performance regulations, mobile source exhaust gas and evaporative loss control devices, traffic flow improvement plans, ride sharing/public transportation systems and other programs to reduce traffic volume.	• Implementation is carried out primarily at provincial/municipal level. • The Air Pollution Control Law of 2000 The Air Pollution Control Law of 2000 gives the national agency (SEPA) limited responsibilities for implementation of selected nationally mandated control programs. • Implementation is believed to be comprehensive, with practically all controlled sources "captured" by the implementation process and brought into compliance. • Source surveillance/monitoring is limited due to limited capacity of municipal/district/county environmental agencies.
Evaluation/ Modification of Controls	• Source surveillance is extensive and forms a key component of implementation. • Evaluation of the effectiveness of control strategies carried out constantly, by evaluating air quality concentrations in response to control plans. • Control plans (SIPs) are "works in progress" and are updated and modified as necessary based on evaluation of effectiveness. • All SIP plans must include contingency measures that can be implemented in short time frames whenever the area fails to demonstrate the anticipated air quality improvements. • When an area fails to meet air quality goals within the specific time period for compliance the area is redesignated to the next highest level of severity and is then subject to the increased requirements of the next higher designation level.	• Evaluation of effectiveness of control strategies takes place in line with 5-year planning cycle, and occurs largely towards the end of each 5-year planning period. • Control strategies are developed on a 5-year planning basis, and are generally revised every 5 years. It is not clear to what extent evaluation of past success affects the planning process for the subsequent 5-year period. • Evaluation of air quality management plans takes place almost entirely at the municipal level.
Roles and Interaction of Government Levels	Federal level: • Provides guidance and suggested approaches to states for development of SIPs. • Develops mobile source control requirements (e.g., motor vehicle controls, motor fuel standards) and some source specific emissions limitation goals, (e.g., the SO_2 cap and trade program, content requirements for products that contain ozone depleting compounds. • Provides technological control standards for some sources (RACT, BACT, MACT, etc.) that are implemented through new source performance	National level: • Provides basic, nonenforceable guidance to provincial/municipal level governments for establishing AQ management plans. • Develops some control measures (e.g. total load control caps, emission standards for industry). • Carries out nationwide industrial surveys/emission inventories (e.g.1995 survey). • Coordinates monitoring efforts of municipalities into a national network.

Table III-1. Comparison of U.S. and China AQ Management Programs

Management Process Step	U.S.	China
	standards, and national emissions standards for hazardous air pollutants. • Operates national monitoring network • Approves SIPs and monitors the progress toward attainment of the NAAQS. • EPA may impose federal plan (FIP) when States fail to develop an adequate SIP, in which case a control plan is developed and implemented by U.S. EPA . • EPA has direct administrative implementation authority; can directly compel sources subject to an operating permit to comply with federal regulations. • Participates in evaluation of SIPs and decisions to revise SIP as needed. State level: • States operate air quality monitoring networks and recommend the boundaries of the regions included in areas that are designated as nonattainment for NAAQS. • States develop detailed AQ management plans for nonattainment areas within their borders, including developing statewide inventory, conducting analyses, administration of permit programs, developing SIP, presenting it to U.S. EPA for approval, and implementing approved SIP. • May have to harmonize plan with regional AQ management programs (e.g. the Northeast Ozone Transport Region ozone management program). • State-level agencies also participate in implementation; have authority to compel compliance with SIPs, state regulations, vehicle inspection and maintenance programs, motor fuel composition requirements. • Participates in evaluation of SIP effectiveness and decisions to revise SIP as needed.	• SEPA has no direct enforcement authority; can not compel action at the municipal level or directly compel compliance by sources, except for extreme cases, which must be brought before the State Council. • Reviews and provides comments on AQ management plans developed by municipal governments. Municipal level: • Develops detailed AQ management plan for area within its jurisdiction, including developing municipal emissions inventory, selecting sources to be controlled and control measures, presenting plan to SEPA for review, and implementing plan. • Implements plan without assistance from national government. Delegates some implementation functions to district/county-level governments. Both municipal and district/county-level governments have authority to compel compliance on the part of air emission sources and can impose sanctions, ranging from fines to closing a facility. • Conducts municipal-level review of effectiveness of AQ management plan; develops new AQ management plans on 5-yr planning cycle.

SECTION IV. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY CONCLUSIONS OF THE U.S. TEAM

Throughout the course of this project, the U.S. component of the U.S.-China management assessment team has been very impressed with the capability and dedication of the air quality management professionals in China who have participated in the project. The U.S. team has learned a great deal about the air quality management process in China, and about the progress made by China's air quality professionals in managing air quality in China's urban areas. Certainly, great strides have been made in improving air quality. In many of China's urban areas, including Shanghai, ambient air pollutant concentrations are trending downward, even in the face of rapid economic development and a rapid increase in economic activity. This is indeed an impressive accomplishment.

Air quality management professionals at the national level and at the Shanghai municipal level have solid, basic capabilities in each of the "building block" areas required for effective air quality management (goal-setting, emissions inventory, monitoring, modeling, control strategy development, implementation, and evaluation). These basic capabilities and the air quality management process used in Shanghai and in China have served the city and the nation well thus far. Using these, Shanghai has identified and instituted control measures for key emission sources that were clearly major contributors to the city's air pollution problems. The control measures taken so far have been effective, and each has helped to move the city's air quality from a severely polluted state to compliance or near compliance with China's ambient air quality standards for key primary pollutants.

As the air quality professionals at SEPB, SEPA, SAES, and CRAES have said throughout this project, however, there are still pressing air quality problems that threaten public health. The ambient air quality standards that have been achieved thus far are still in some cases (e.g., Level III standards in industrial zones) higher than WHO guideline pollutant levels considered protective of human health. In addition, some key pollutants (including secondary pollutants like ozone and $PM_{2.5}$, and toxic air pollutants) have not yet been addressed. Thus, Shanghai (as with Beijing and some of the other urban areas in China) is poised to begin a new phase in air quality management. Having addressed many of the most apparent pollutant sources, but still needing significant additional reductions in air emissions in order to reach ambient pollutant levels protective of human health, Shanghai has reached a point where far more thorough and detailed assessment and analysis will be required in order to identify the most technologically effective and cost-efficient control strategies going forward. Each incremental improvement in air quality from this point on will become progressively more difficult and expensive.

To meet the challenge of continued improvement in air quality in Shanghai, SEPB (and SAES as appropriate) will need to develop more sophisticated capability in each of the basic air quality management building blocks. But beyond this, and perhaps most importantly, these strengthened building blocks will have to be linked together more effectively, into a solid, comprehensive air quality management *process* that is continual and iterative, and will lead to the identification of the most effective and cost-efficient air quality management strategies, policies, and programs for Shanghai in the future.

The recommendations of the U.S. team are therefore focused in two areas: (1) strengthening the building blocks of effective air quality management; and (2) strengthening the overall process for air quality management. The team understands that the situation in Shanghai is indicative of the situation in many of China's major urban areas. The recommendations presented below are likely to be equally applicable, with some adjustment, to China's other urban areas.

B. RECOMMENDATIONS FOR SHANGHAI

The U.S. team's recommendations for strengthening Shanghai's air quality management capability are organized into two phases: a near-term phase, and a longer-term phase. The team recommends that Shanghai should begin immediately to strengthen capabilities and approaches in four of the component building block areas – this is the focus of the near-term recommendations. In the longer term, the team recommends capacity strengthening aimed at developing the capacity to utilize the output from all of the basic building blocks in an overall, stepwise, coherent analytical process – i.e. strengthening the overall ongoing *process* of air quality management.

1. Recommendations for Near-Term Action

As indicated above, it is recommended that near-term action should be focused on strengthening capabilities or modifying the approaches used in each of four of the basic air quality management building block areas. Recommendations are presented below for each area.

a. Goal-Setting

It is recommended that SEPB consider adopting a single, unified ambient air quality goal for each air pollutant of concern. This single ambient air quality goal should be applicable to all areas, regardless of land use or level of industrialization. Most importantly, it is recommended that the air quality goal adopted for each pollutant should be set at a concentration level that ensures protection of human health and the environment. The team recognizes that Shanghai, and China in general, are moving away from the system of three grades or levels of ambient air quality standards, and has established the goal that all urban areas should comply with Grade 2 ambient air quality standards. The U.S. team endorses this decision and recommends that the change be made official on a national-level as soon as it is practical. The approach of segregating urban areas into smaller zones and establishing different air quality goals within these zones seems untenable, given the strong influence of the sources and the air quality in each zone on air quality in surrounding or more distant zones - and indeed the influence of major air emission sources on air quality over a large region. Air quality is a regional phenomenon, and it is recommended that Shanghai address air quality on a consistent basis citywide, rather than applying different air quality goals to smaller zones within the city.

The U.S. team understands the approach in China and Shanghai of setting goals at attainable levels, treating goals as incremental steps towards the ultimate objective of protecting human health and the environment. It is further recognized that goals set at WHO guideline levels for protection of human health and the environment (or levels near these guidelines) may not be attainable for several years, or perhaps within the next one or two five-year planning cycles. Nevertheless, as Shanghai strengthens its air quality management process, and begins to apply more sophisticated data gathering, air quality modeling, and management planning tools, it will become more efficient and effective in the long term for Shanghai to apply these tools and plan towards a single, ultimate air quality goal, rather than a series of incremental steps towards that goal.

Finally, it is recommended that Shanghai expand its air quality goal-setting to include additional secondary pollutants. The most important of these secondary pollutants are O_3 and size segregated particulate matter (e.g., PM_{10}, and fine particulate matter). While O_3 and PM_{10} are included in China's Ambient Air Quality Standards list, they have not been the focus of significant air quality management efforts to date. Goals should also be established for a fine particulate matter size range, as evidence indicates that the smaller particles represent the most serious health effects. In the U.S., standards have been established for $PM_{2.5}$, however, another convenient fine particulate matter size range could be just as effective in Shanghai, and additional research should be completed to determine an appropriate size range that is consistent with health protection goals and conditions in Shanghai and more generally for all of China. Consideration of these other important health related pollutants early in the efforts to upgrade and expand air quality management in China, will allow comprehensive control strategies to be developed. The experience of the U.S. and other countries that have been addressing air quality issues for many years suggest that a comprehensive approach will have the maximum benefits for reducing the overall public health risk at the lowest cost, relative to an approach that is based on incremental goals and/or pollutant specific goals.

b. Emissions Inventory

Improved and expanded emissions inventory development methodologies are critical, to address current and emerging air quality issues in Shanghai and other cities in China. A more comprehensive inventory will support much more sophisticated modeling and assessment, and ultimately the identification of more effective and cost-efficient control strategies. While other components of the air quality management process such as monitoring, modeling, and economic analyses typically require more specialized training and funding commitments, they cannot be effectively completed without first having access to a comprehensive and reliable emissions database. Therefore, this is the first and primary need that must be addressed in Shanghai and in China generally. The steps required to significantly improve the emissions inventory capabilities in Shanghai extend beyond the adoption of methods for pollutants and sources that have been neglected to date. The physical location of sources, effects of smoke stacks, the timing of emissions and the existing levels of control that have been applied to various sources are all important types of information for the applications that inventory data will be used to support. It is reasonable to approach the development of a comprehensive emissions inventory in a cycle that covers several years. This will allow limited resources to be used effectively to achieve the most beneficial improvements in the data representing the different source sectors. For example, improvements could be made on a three-year cycle, in which mobile sources, area sources and point sources are the focus of efforts respectively in years 1, 2, and 3. Then the cycle can be repeated to incorporate new data, and techniques that become available. Specific recommendations related to emissions inventory methods include:

- Establishing a formal plan with a definite schedule for improving emissions inventory techniques and databases;
- Development of an inventory of area sources, including anthropogenic and biogenic sources, fugitive dust, etc. Good emission source terms should be developed for each source type;
- Development of a comprehensive mobile sources inventory, including all on-road and nonroad mobile sources;
- Completion of the coverage and verification of the stationary source inventory data;

- Expansion of the emissions inventory to cover additional pollutants beyond SO_2, NO_x, and TSP – particularly, for the important precursors for ozone and fine particulate matter (e.g. VOCs, NH_3, etc);
- Application of emissions inventory estimation and modeling techniques (e.g., Mobile Source emission factor models, techniques to estimate future-year emissions, etc.) to the more comprehensive emissions data developed according to the above steps, to derive a city-wide picture of emissions adequate for urban scale modeling;
- Ensure that the spatial locations, smoke stack parameters, and temporal operating cycles are represented in the emissions inventory for all sources (these additional data are necessary to enhance the capacity to study the issues related to regional and local transport and chemistry of air pollutants);
- Development of the inventory into a spatially, temporally and chemically resolved emissions inventory, suitable for use in research efforts to understand the interaction of city-wide emissions, and the formation of photochemical air pollutants, (e.g., fine particulate matter, O_3, NO_x, etc.).
- Ensure that the existing control measures and control efficiencies are represented in the database, to facilitate the analysis of additional or more stringent control options;
- Develop approaches and data sets to allow the creation of projected emissions inventory data to represent future-year conditions; and
- Initiation of a regional assessment to evaluate the impact of major municipal/industrial areas upwind of Shanghai and the impact of Shanghai's emissions on the other areas.

c. Monitoring

SEPB is working to expand the air quality monitoring network in Shanghai. Many specific recommendations and suggestions for strengthening the monitoring network were developed in the report developed under a U.S. Trade Development Agency contract for the Shanghai Environmental Protection Bureau, (SEPB, 2002). The U.S. team endorses this effort, and encourages the adoption of the recommendations in that report. Strengthened monitoring will provide more comprehensive air quality data, which will allow more precise identification of air quality problem areas and pollutants. The improved data will (1) facilitate efforts to prioritize the most critical issues, (2) allow better evaluation of the effectiveness of control measures, and (3) support verification of modeling output and fine-tuning of models.

Recommendations for strengthening air quality monitoring include:

- Expansion of monitoring capability to cover additional pollutants (or cover them in more stations), in particular:
  - Secondary pollutants (O_3, fine particulate matter);
  - Important precursors of these secondary pollutants (VOC, NH_3); and
  - Air toxics (Pb, B[a]P, phenols, etc);
- Expand filter analysis capability, including development of source profiles;
- Establish routine meteorological monitoring capabilities to augment the ambient air quality data and to serve as input to model simulations of urban air quality; and

- Establish monitoring sites in upwind and downwind locations to facilitate analyses of the influence of air pollutants that are transported into the Shanghai area and the influence of sources in Shanghai on downwind areas.

d. Modeling

The following steps are recommended for strengthening air quality modeling capability in Shanghai. Since modeling capabilities are closely linked and directly dependent on emissions inventory capabilities these recommendations for strengthening modeling capability should be considered along with the recommendations for emissions inventory activities presented above.

It is recommended that SEPB consider the wide range of modeling tools now available in the U.S. and carefully select and adapt modeling tools to fit Shanghai's current conditions, needs, and data availability. As indicated in Section II, sophisticated modeling capability evolved in the U.S. over more than 2 decades, and was developed to meet the specific needs and data availability in the U.S. It is recommended that Shanghai set the eventual goal of developing modeling capability similar to that of U.S. EPA's Models-3, as inventories and data become available in future years to support such a capability.

Strengthened modeling capability will provide valuable tools to support the identification and selection of control strategies that are effective, cost-efficient, and tailored to each situation, by allowing simulation and comparison of the likely effectiveness of different control strategies. Modeling techniques, however, represent approximations of the complex processes associated with atmospheric phenomena and as such they are subject to significant uncertainties. Extensive training is critical to develop the experience necessary to interpret modeling results given the specific conditions that effect any given location and source mix situation. The Shanghai area and other urban areas in China are no exception, and the efforts to enhance local and national modeling capabilities should recognize these limitations. The recommendations to enhance modeling capability include:

- Initiation of a short-term modeling effort for the assessment of emerging secondary pollutant issues such as O_3 in Shanghai using the modeling tools provided by U.S. EPA such as OZIPM/EKMA;
- Initiation of research efforts and staff training to understand the formation of photochemical air pollutants, e.g., fine particulate matter, O_3, acid rain, etc., in Shanghai;
- Development of comprehensive photochemical (reactive) modeling capability for the simulation of multiple pollutants, primary and secondary aerosols, O_3, visibility, acid deposition, etc. in the Shanghai airshed, based on the modeling tools provided by U.S. EPA (Models-3/CMAQ);
- Initiation of a regional assessment to evaluate the impact of upwind major municipal/industrial areas on Shanghai and the impact of Shanghai's emissions on the other areas;
- Initiation of research to develop more robust meteorological data to support modeling, including research of micrometeorological effects of the increasing number of tall buildings, and the influences of natural terrain, the land/sea interface, and other land use characteristics;
- Adoption and application of receptor modeling and source apportionment tools as a means of identifying the most important sources of ambient air pollutants. Models available in the U.S. include (U.S. EPA, 2001e);

- The Chemical Mass Balance (CMB) models, which compare speciated emission profiles of known source categories to speciated ambient monitoring data to estimate the average relative importance of each of the source categories to ambient fine particulate matter concentrations on the day of monitoring; and
- Multivariate statistical models such as the Positive Matrix Factorization (PMF) and UNMIX models. These models assist in identifying key source categories where these are unknown, and provide estimates of "average" rather than day-specific contributions. As such, they may be particularly useful to identify the most important sources, and for applications related to attainment of annual ambient air quality standards.

2. Recommendations for Longer-Term Action

In the longer term, as the approach and capabilities in the above building-block areas are strengthened, it is recommended that SEPB begin to apply all of the air quality management components in a coordinated, highly analytical process. The strengthened emissions inventory, modeling, and monitoring capabilities would be used in a coordinated manner to provide a comprehensive understanding of the links between various air emission source types in Shanghai and their contribution to both primary (human health based) and secondary (environmentally based) pollutant levels in the ambient air. The strengthened tools would permit comparative analyses of the effects of various control strategies, and would support selection of a control strategy tailored specifically to the conditions of Shanghai. The new tools will also support more effective, real-time evaluation of control strategies, and more frequent adjustments in controls as needed.

The primary recommendation to SEPB for longer-term action, then, is to build capacity to use the outputs of the strengthened inventory, monitoring, and modeling tools in a coordinated, analytical process to identify, assess, compare, and evaluate control strategies. This capacity building would best be accomplished through training and through first-hand exposure to, and participation in, a process similar to that used in the U.S.

Some specific longer-term recommendations are presented below.

a. Controls

Since many of the obvious issues (e.g., widespread residential and industrial coal combustion) have already been addressed in Shanghai, further control strategies should be developed only after full analysis of potential effects, costs, and benefits, using the strengthened tools as described above. A critical consideration in the long-term planning process is that control strategies need to be developed to address the future air quality conditions that account for the full effect of control strategies and the growth in source strengths. This will require the development of not only a comprehensive current emissions inventory, but also techniques to project emissions strengths and locations to represent future year conditions when air quality goals are to be achieved. The full spectrum of technical and economic analyses cannot be applied to efficiently develop an achievable air quality management strategy without first having the capability to complete analyses of future year conditions.

As an example, the strategy used in Shanghai that simply moved sources to locations further away from existing population centers may be counter productive over the long term. Normal population growth and transportation systems used to get workers to these relocated facilities might actually result in worse problems in the future. At best that type of strategy will only delay the need to address the underlying cause of the air quality issue. If a strategy based on facility relocation is to be implemented, SEPB might consider further requirements to limit ancillary growth in those areas, and to require facilities to provide and maintain a convenient transportation system for workers to limit the potential for negative side effects.

For these and other related reasons, it is necessary to evaluate the consequences of proposed control strategies in a comprehensive way to ensure that effective and efficient solutions are adopted. Thus the following recommendations should be considered in the longer term, after the capability to assess the full range of consequences of any proposed strategy has been developed.

It is recommended that Shanghai and SEPA, at the national-level, work to define a "toolbox" of control measures, including source category- and pollutant-specific technology controls, health-based controls, and economic incentives. Shanghai could serve as a pilot study and example for the rest of the country regarding selection of the optimal mix of tools to apply in various situations. An important component of this process is to define, to the extent possible, the monetary costs of the control requirements relative to estimates of the monetary benefits achieved through the implementation of the specific control measures. Shanghai would then assume a leadership role in guiding other urban areas in the development and application of effective control strategy development programs.

Key recommended measures include:

- Expanding emission controls to cover additional pollutants beyond TSP, SO_x, and NO_x – particularly VOCs, CO, specific air toxics, and NH_3, and a much broader collection of source categories – particularly area and mobile sources, which are important precursors to O_3 and fine particulate matter;
- develop a combination of controls, encompassing the national regulations (emission standards, nationally-imposed emission caps), but also incorporating local measures specific to Shanghai's situation;
- Local controls measures to be considered include:
  - Individual emissions limits focused on key sources/activities and pollutants; and
  - Permit/emission fees program;
- Market-based emissions cap and trading programs consistent with the following conditions:
  - The key to an effective emissions cap and trade program is to ensure a robust trading market that offers a large number of facilities that are willing to sell emissions credits and a large number of facilities that need to purchase credits; and
  - A comprehensive preliminary study to assess the market conditions and trading rules associated with a cap and trade program is necessary to ensure that the program is established in a way that will result in economic benefits and measurable, cost-effective emissions reductions (for example, a sulfur dioxide trading program limited to Shanghai may not result in a sufficient market to achieve the cost savings that are possible with such emissions trading programs operated over a larger area);
- Examine the permit/emissions fees approach as a tool for strengthening incentives for emissions reduction, and/or for covering EPB operating costs. Initial questions that would have to be answered include:

- The purpose of fees (e.g., to cover permitting costs, to provide a disincentive for emissions);
- The best fee structure (e.g., flat fees, different fee levels); and
- Fee levels; these should be carefully adjusted through economic analysis, to ensure that fees are maintained at levels that accomplish the intended purpose, without creating undue economic burdens on responsible facilities.

- Promote requirements for all new and expanding facilities to adopt processing and manufacturing technology that includes the concept of pollution prevention to force future economic growth that results in the lowest possible emissions rates;
- Continue and expand the existing mobile source control programs including emissions standards for new cars, continued conversion of part of the taxi fleet and urban buses to LPG and CNG engines, and improved programs to ensure compliance with mobile source standards;
- Complete a study of current traffic flow patterns and anticipated traffic flow patterns as the number of personal use vehicles increases to define appropriate traffic control measures to ease congestion at critical locations in the city; and
- Examine the potential for selected voluntary programs with appropriate incentives to encourage deeper emissions reductions in shorter time periods than are likely to be achieved under a regulatory approach.

b. Implementation

Recommended measures to strengthen implementation include:

- Increase the public availability of data regarding air quality management, establish mechanisms for meaningful public input, and encourage public participation in air quality management decisions and implementation;
- Consider a system to track compliance with emission limits, as well as inspection and enforcement tools, such as are included in Method 9 in the U.S.; and
- Establish a national training center in Shanghai to transfer the skills and experiences developed in Shanghai to air quality professionals in other parts of China.

c. Control Strategy Evaluation/Modification Process

It is recommended that, once the necessary tools are fully developed, the process of evaluating and adjusting air quality control strategies should be given significantly more emphasis than it receives now. Evaluation should be a constant process, and progress should be evaluated relative to specific numerical air quality goals that have definite schedules for achieving those goals. It is recommended that flexibility be increased within the 5-year planning cycle to allow a constantly evolving process, wherein adjustment to control strategies can be implemented as and when the need becomes apparent.

It is further recommended that control strategy evaluation should include an economic evaluation of the costs and benefits associated with proposed and implemented controls. These evaluations should include evaluation of the health benefits achieved (e.g. increased worker productivity, new jobs created by environmental technologies, avoided health care costs, etc.), as well as property damage benefits, etc. Such analyses will assist in demonstrating the value of strengthened air quality management – which will become increasingly necessary as controls become more costly for each incremental improvement in air quality.

3. National Level Policy Recommendations

The bulk of the recommendations for enhancing urban air quality management in China are focused at the municipal level, largely because the bulk of the activity in managing urban air quality is carried out at that level. Nevertheless, the U.S. team has several recommendations for enhancing air quality management at the national level. These are outlined below.

a. Air Quality Management Process

It is recommended that SEPA should take measures to encourage development of the air quality management process recommended above for Shanghai, nationwide. Adoption of air pollution control measures on individual regional or urban areas can result in competitive inequities between regions. Since many of the serious air pollution problems are regional in nature, different local control requirements can be counter productive especially in densely populated industrial areas such as Eastern China.

SEPA should work cooperatively with other national-level agencies to actively encourage all municipalities with air quality issues to enhance their basic air quality management building blocks (goal-setting, inventory, monitoring, modeling). The movement toward national air quality and emissions standards for those source categories that are found in all major industrial centers in China should be accelerated. An analytical approach involving urban scale modeling should be promoted at the national-level for all urban areas as a means of identifying cost-effective local control strategies to augment the national emissions standards. Finally SEPA should consider establishing a national level research and education capability to promote pollution prevention concepts as the economic development continues throughout China. This program can identify advanced processing and manufacturing technologies that are being applied in developed countries to reduce the quantity and severity of air pollutants generated at the source. The use of pollution prevention approaches will help reduce the potential for new development to compromise the progress that has been made to date, and will achieve maximum air quality benefits at lower cost than the alternative of adding pollution removal equipment later on.

Implementation of the above recommendations in Shanghai could serve as a pilot project, demonstrating the long-term value in terms of costs and benefits of a thorough analytical approach to air quality management for China's urban areas. It is recommended that a program be developed at the national-level to transfer the experiences and lessons learned, as well as the tools developed, in Shanghai to other cities in China at similar stages in development and air quality management.

b. Goal Setting

It is recommended that the National Ambient Air Quality Standards be revisited. As discussed above, it is recommended that these standards be set based on protection of human health and the environment. The standard for each pollutant should be set at a level known to be protective of human health and the environment. It is further recommended that the current, three-tiered system be de-emphasized, in favor of a single, uniform primary ambient standard based on human health protection for the air pollutants that are important in all urban areas in China.

c. Control Measures

The following recommendations are offered concerning national-level control measures:

- The national emission standards described in Section I.A.2.d should be periodically reviewed and updated, to ensure that they remain appropriate to current technological advances and economic conditions. As technology improves and the country becomes generally more affluent, more stringent air emission limits can become more technically and economically feasible, and may be considered for adoption;
- SEPA should consider issuing or adopting national technology standards, which establish emission limits based on levels of control technology that are consistent with economic, legal, and political limitations. These could be similar to the "reasonably available control technology"(RACT), "best available control technology" (BACT), and "maximum achievable control technology" (MACT) standards issued through federal regulation in the U.S. The adoption of stringent, yet technically feasible emissions standards, will encourage the construction of new facilities that use state of the art processing and manufacturing techniques that minimize pollution at the source, and will provide local governments with more tools or options that can be included in local air quality control strategies; and
- Emissions standards and programs related to mobile sources should be adopted and managed at the national-level to avoid the potential for an inefficient and confusing set of city-specific mobile source control programs.

d. Implementation and Training

- SEPA's authority should be expanded to include a more proactive role in the air quality management process. The following specific activities should be considered:
  - Establishing minimum air quality management requirements applicable in all areas;
  - Review and approval functions to help ensure consistent national programs that apply equally in all urban areas and to facilitate the adoption of proven approaches in all areas of the country;
  - Encourage requirements for public participation in national and local decisions regarding air quality management programs;
  - Establishment of national control over the testing and enforcement activities associated with mobile source standards and fuel requirements; and
  - Implementation of a minimum level of enforcement functions;
- SEPA should consider establishing a national-level training program for selected air quality management functions, including:
  - Emissions inventory method development, and implementation requirements;
  - Air quality monitoring procedures; and
  - Air quality modeling approaches and techniques;
- SEPA should consider adopting approval and control functions to govern the establishment of coordinated multi-pollutant implementation strategies;

- SEPA should make recommendations on the approaches that can be used to estimate cost and benefits of various control strategies to promote the adoption of consistent procedures in all areas and to facilitate the comparison of cost/benefit analyses among the various cities and regions; and
- Finally, SEPA should consider establishing a nationally consistent set of procedures applicable to proposed emissions cap and trade programs.

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APPENDIX A
Project History Summary

April 1999 Statement of Intent

On April 9, 1999 in conjunction with the official visit of Chinese Premier Zhu Rongji to the U.S., then-EPA Administrator Carol Browner and China State Environmental Protection Administration (SEPA) Director Xie Zhenhua signed a Statement of Intent (SOI) creating the U.S. – China Air Quality Management Assessment Project. The SOI recognized that air pollution is an important public health issue for both countries, and that current trends are likely to result in increased population exposures to potentially harmful pollution levels in large cities. U.S. EPA and SEPA agreed that the project's goal would be exchange of information, technology, policy approaches, analytical tools, and experience in each country's air quality management system in order to improve air quality in China, the U.S., and the world.

Project Launch Meeting

U.S. EPA and SEPA held the first series of project planning meetings in Beijing from November 15-19, 1999. The U.S. delegation was led by Ms. Charlene Spells of U.S. EPA's Office of Air Quality, Planning and Standards U.S. EPA/OAQPS). The U.S. EPA team also included technical experts in the areas of air quality management, air quality monitoring, emissions inventory preparation, and air quality modeling. Chinese participants included representatives of SEPA, the China Research Academy of Environmental Sciences (CRAES), Peking University, Tsinghua University, the National Monitoring Center, the National Environmental Analysis Center, the Beijing Environmental Protection Bureau (BJEPB), and Shougang Steel Group. The delegation was welcomed by Mr. Fan Yuansheng, Deputy Director of SEPA's Department of Pollution Control. During site visits to CRAES, BJEPB, and Shougang, the U.S. EPA delegation was welcomed by CRAES Director Chen Fu, BJEPB Deputy Director Yu Xiaoxuan, and Shougang Assistant Manager Liu Shuiyang. The U.S. EPA delegation was accompanied during the entire visit by Dr. Zhao Weijun, Director of SEPA's Division of Air and Noise Pollution Control.

During these meetings, U.S. and Chinese experts presented background and technical information on air quality and air quality management in the U.S. and China. The U.S. EPA delegation prepared a collection of technical materials and made a series of detailed presentations on U.S. EPA procedures in the areas of air quality management, air quality monitoring, emissions inventory preparation, and air quality modeling. SEPA and U.S. EPA project leaders and experts also discussed and agreed upon initial activities to be undertaken by the Project, including preparation of an Assessment Report to describe and evaluate air quality management systems in China and the U.S., and the holding of a major U.S.-China Air Quality Management Workshop to allow for further exchange of information and experience between the two sides.

April 2000 Beijing Workshop

With the strong basis for further cooperation established by these initial meetings, U.S. EPA and SEPA planned and implemented a major technical workshop on air quality management. The workshop was held April 26-28 in Beijing, and was jointly sponsored by SEPA, U.S. EPA, and the National Institute of Public Health and Environmental Protection of the Netherlands. The workshop's primary objective was to provide a forum for the exchange of information on the Chinese and U.S. approaches to understanding and managing air quality. Representatives from the U.S. and Europe presented information on the scientific bases for establishing ambient air quality standards and developing implementation programs. Chinese officials and experts presented information on air quality trends in major Chinese urban areas and pollution control efforts in China. Given it's importance in both the U.S. and China, particulate matter (PM) regulation was used as a case study. Workshop sessions included:

1. Overview of the pollution control situation and pollution trends in China, the U.S. and Europe;
2. Status of air pollution control in China;
3. Particulate matter air pollution in China;
4. U.S. particulate matter standards development;
5. Particulate matter standards implementation;
6. Mobile source emission control: integrated approaches;
7. United Nations Economic Commission for Europe's approach to fine particulate regulation;
8. Scientific basis for the 1997 revision of PM NAAQS;
9. Health effects associated with fine and coarse fraction particles;
10. Air quality characterization;
11. Ambient air quality monitoring;
12. Advances in Dutch particulate matter regulations;
13. Status of air pollution in Chinese cities;
14. Air quality management in China;
15. U.S. PM standards implementation;
16. Colloquium on local/regional air quality management issues with presentations by Chinese environment protection bureau representatives and U.S. State/local representatives;
17. Making clean air programs work: the Los Angeles experience; and
18. California perspective: air quality management for particulate matter.

More than 50 experts from government agencies, international organizations, research academies, and universities participated in the workshop. Workshop participants included officials from SEPA and U.S. EPA, experts from the Chinese Research Academy of Environmental Sciences (CRAES), experts from the U.S., Switzerland and the Netherlands, experts and officials from Chinese universities, scientific research institutes, monitoring centers, officials from local Environmental Protection Bureaus (EPBs) and members of the Pollution Control Working Group of the China Council for International Cooperation on Environment and Development (CCICED-PCWG). The Pacific Institute for Environmental Research (PIER) served as the workshop organizer and facilitator. The Chinese delegation to the workshop was led by Mr. Fan Yuansheng, Deputy Director of Pollution Control Department of SEPA and Mr. Zhang Shigang, Deputy Director of International Cooperation Department of SEPA. The U.S. EPA delegation was led by Ms. Charlene Spells, U.S. Project Director, Mr. Jeffrey Clark, Director of Policy and Communications, Office of Air Quality Planning and Standards, and Dr. Lester D. Grant, Director of the National Center for Environmental Assessment.

Of particular note at the workshop were two breakout sessions, which allowed more detailed presentation and discussion. The first Breakout Group discussed the health effects associated with PM pollution. The second Breakout Group addressed the implementation of PM regulations. Additional issues were presented regarding local and regional air quality management. Officials from local EPBs made presentations addressing local points of view on air quality and air pollution trends, major emission sources, approaches for evaluating air quality, approaches used to identify and implement control measures, enforcement of environmental regulations, the role of emissions permitting, the implementation of a pollution levy system, and environmental management policy and future air pollution control measures.

In order to maximize the flow of information, each workshop presentation featured question and answer sessions and numerous informal discussions during the presentations in which valuable information was exchanged. The air quality management experiences related by the U.S. and European delegates gave the Chinese participants a very useful reference to consider for the addressing the air quality issues in China. The U.S. and European delegates, in turn, gained a better understanding of the current air quality management system and approaches currently in place in China. Finally, after completion of the second day of the workshop, the international delegation had the honor of an audience with Professor Qu Geping, Chairman of the Environment and Resource Protection Committee of the Standing Committee of the National People's Congress. Professor Qu made a brief statement and addressed questions regarding the air pollution situation and policies in China.

Selection of Chinese Demonstration City

Based on information exchanged during the Workshop, SEPA, U.S. EPA, and representatives of local EPBs held continued discussions in order to select a target Chinese demonstration city for the Assessment Report and for initial targeted cooperative activities. Due to the wide-ranging nature of its air quality problems and the enthusiasm demonstrated by its municipal government and local EPB, Shanghai was ultimately selected to be the demonstration city. This decision was made during the latter half of 2000, and was followed by meetings February 26-28, 2001 in Beijing between SEPA, U.S. EPA, and representatives of the Shanghai Environment Protection Bureau (SEPB), the Shanghai Academy of Environmental Sciences (SAES), and the Shanghai Municipal Environmental Monitoring Center. During these meetings, U.S. EPA and SEPA introduced representatives of these Shanghai institutions to the project, discussed development of the Assessment Report, and began discussions of possible post-assessment cooperative activities. It was first agreed that the Assessment Project team will conduct an focused information exchange activity in Shanghai in May 2001 consisting of in-depth, 2-way technical information exchange between the Chinese and U.S. participants and including 2-3 day preliminary training on air quality monitoring for Chinese participants from SEPB, SEPA, CRAES, and SAES. U.S. experts would also use this opportunity to collect information from Chinese experts in order to assess the status of air quality management in Shanghai and identify gaps and opportunities to strengthen air quality management in China.

Meeting participants also discussed in detail and agreed upon a working outline for the Assessment Report. Both sides also agreed in principle that a brief visit to the U.S. by Chinese officials and experts should take place to allow the Chinese participants to attend training sessions on aspects of air quality management and review the draft Assessment Report with U.S. EPA representatives. While funding was not currently available for this visit, both sides agreed to investigate and develop possible funding sources.

It was also agreed that during the drafting of the Assessment Report, needs for further capacity building for air quality management in China would be assessed and identified in the Report. Possible capacity building activities included a study tour by Chinese air quality experts to the U.S., technology transfer, and provision of air quality management equipment and software.

May 2001 Shanghai Expert Meetings and Training

As planned during the February 2001 meeting, U.S. EPA prepared and dispatched a nine-person technical and project expert group to Shanghai, China for meetings May 14-18. The goals of these meetings are listed below:

1) Review progress of project activities to date;
2) Conduct technical exchanges between U.S. and Chinese experts;
3) Conduct site visits to locations related to air quality monitoring in the Shanghai area;
4) Collect and review information for Assessment Report;
5) Develop initial technical and policy recommendations for air quality management in China and Shanghai; and
6) Conduct an initial training in U.S. monitoring approaches for Chinese monitoring officials and experts.

U.S. and Chinese experts in the areas of monitoring, modeling, emissions inventory development and use, permitting, control strategy development, and overall air quality management systems conducted technical exchanges and developed the following conclusions.

Modeling and Emissions Inventory Development and Use

U.S. and Chinese experts held three days of technical exchanges on updated modeling and emissions inventory development. U.S. experts presented U.S. approaches in inventory development and modeling and also transferred several tools to the Chinese side (AIRCHIEF 8.0, emissions inventory training course materials, inventory estimation methodology). The U.S. EPA team also installed a new advanced air quality model U.S. EPA Model-3/CMAQ) at SAES, allowing consideration of over 100 chemical reactions compared to models currently in use in Shanghai which consider about a dozen reactions.

Based on these discussions, the U.S. and Chinese experts reached the following conclusions:

1) Based on current and emerging air quality issues (e.g., PM 10, PM 2.5, O_3, NOx, SO_2, etc.) in Shanghai, Shanghai should consider expanding and improving current emissions inventory to include additional database and information system for studying these air quality issues (e.g., VOC, PM, NH_3, off-road emissions, biogenic emissions, fugitive dust, etc.);
2) Enhance the capacity to study the issues related to regional and local transport and chemistry of air pollutants and emission inventory database and modeling;
3) Initiate a short-term modeling effort for the assessment of emerging secondary pollutant issues such as O_3 in Shanghai using the modeling tools provided by U.S. EPA such as OZIP/EKMA;
4) Initiate research efforts to understand the formation of photochemical air pollutants, e.g., PM 2.5, O_3, NOx, etc., in Shanghai; and

5) Initiate a regional assessment to evaluate the impact of upwind major municipal/industrial areas on Shanghai and the impact of Shanghai's emissions on the other areas;

Air Quality Monitoring

U.S. and Chinese experts met for three days of technical exchanges on air quality monitoring, including one day of intensive training. The training was presented to 30 staff-persons from the Shanghai Monitoring Center, including planning and design staff, lab staff, data related staff, and Quality Assurance/Quality Control (QA/QC) staff. It was a good, well-selected audience for the training and the training was well-received by the Chinese side. In conjunction with the training, U.S. EPA also distributed technical training materials to the participants. Based on the successful conclusion of the training, it was agreed by the U.S. and Chinese experts that there should be a further refinement of the training courses in those areas most relevant to Shanghai's needs, development of Shanghai-specific case studies, and translation of training materials by the PRC side so that the expanded training could become a component of general monitoring center staff training in the future. This work would also provide the basis for extension of the training program to other Chinese cities.

In addition to the training, U.S. and Chinese experts also conducted technical exchange, and came to the following conclusions:

1) Given Shanghai's expansion over the years and changes in the economic structure since the monitoring network was constructed, U.S. and Chinese agreed that the network's coverage area and spatial distribution is inadequate and that the monitoring network must be expanded. The experts also discussed the need for modernization of certain technologies to ensure that the data is consistent with further regulatory developments and policies;
2) U.S. and Chinese experts discussed the current situation in Shanghai regarding ozone and evaluation of that information as an assessment tool, which may be very important in later years when ozone becomes a more important environmental issue. U.S. and Chinese experts agreed that ozone and hydrocarbons should be monitored on an ongoing basis. U.S. and Chinese experts also discussed the need to provide specialized training for the monitoring staff in Shanghai that covers such emerging issues as PM2.5, sampling and analysis of fine particles, and sampling and analysis of air toxics;
3) Chinese experts expressed the view that QA/QC should be continuously improved and routine training should be strengthened. Regarding PM2.5, while SAES began a study last year, this is preliminary work and Shanghai would benefit greatly from the longer U.S. experience. Chinese experts also stated that China could benefit from the U.S. experience in the use of source apportionment approaches as a tool for air quality assessment and management;
4) The U.S. expert also commented on the height of monitoring equipment placement and its relationship to exposure levels, which Chinese experts said should be given more consideration in the future, particularly when U.S. and Chinese experts establish additional stations for vehicle emissions monitoring; and
5) Chinese experts expressed their hope for continued technical exchange and capacity building in the future, particularly in the areas of network expansion design, $PM_{2.5}$ monitoring approaches, source apportionment, techniques to monitor photochemical pollutants, and air quality forecasting. Chinese experts also expressed the hope that a long-term relationship could be established between the Chinese and U.S. EPA monitoring groups.

Permitting

U.S. and Chinese experts summarized the use of permits in the U.S. and recommendations for Shanghai as follows:

1) Chinese experts stated that one of the most important issues now under consideration by SEPB is allocation of permissible emissions among individual sources based on the overall regional emissions limits allocated to Shanghai by SEPA under China's Total Emissions Control Program. Chinese experts said they would like to benefit from understanding U.S. approaches in development and administration of allowable emissions through State Implementation Plans (SIPs) and permits to aid them in this process;
2) Chinese experts expressed the conclusion that the strong legal basis undergirding the permit system and determination of allowable emissions amounts in the U.S. allows for easier implementation of the program by the regulation agency, and that this legal basis and sources' familiarity with it also improved compliance. Chinese experts also emphasized the benefit and importance of public participation in the permit development process, of establishing permit fees in accordance with an established legal process, and that regulated enterprises should adopt efficient monitoring and reporting techniques; and
3) The Chinese side expressed its hope for continued technical assistance and capacity building support in this area in the future.

Based on these views, the U.S. expert made the following general recommendations:

1) Establishment and strengthening of enforceable emissions limits;
2) Establishing emissions limits for additional pollutants (e.g., toxics and ozone);
3) Further incorporation of citizen comments in developing environmental regulations;
4) Link expansion of the allowance trading program to other control measures;
5) Development and assessment of permit fees for emissions permits:
    i) Determine the purpose(s) of fees to be charged (cover admin costs, other purposes, etc.); and
    ii) Review U.S. guidance documents provided by U.S. EPA;
6) Compliance and enforcement:
    i) Consider stricter penalties; and
    ii) Consider self-reporting by sources to reduce the inspection burden.

Control Strategy

U.S. and Chinese experts made the following basic conclusions and recommendations for control strategy development in Shanghai:

1) There are many areas of similarity between the U.S. and Chinese approaches, but also differences. This means that while there are areas in which China can draw on the U.S. experience, China's and Shanghai's specific circumstances must always be taken into consideration;

2) Characterize sources, concentrations, and transport:
   i) Expanded monitoring system and chemical speciation;
   ii) Use of source apportionment tools for chemical analysis of ambient samples;
   iii) Further emissions inventory development for all relevant sources and precursors (including ammonia), meteorological data to support use of advanced models such as Models-3; and
   iv) Evaluation of transport in and out of the airshed;
3) Set ambient AQ goals to protect health:
   i) Chinese experts agreed that the relationship between air quality and emissions should be studied carefully in order to allow determination of emissions permit amounts based on human health considerations; and
   ii) China must however take cost considerations into greater consideration than does the U.S;
4) Develop a strategy and evaluate the benefits (e.g., avoided healthcare costs, economic benefits):
   i) Individual emissions limits to get to the AQ standards;
   ii) Evaluate and present the economic benefits of worker productivity, avoided healthcare costs, and other economic benefits for individual measures when presenting them for upper level review and approval; and
   iii) Based on discussion of U.S. approaches to setting emissions standards, Chinese experts stated that the U.S. of technology-based performance standards should be considered in China and Shanghai as well and adopted where feasible.
5) Implementation:
   i) Consider establishing permit system and adjust emissions fees as needed;
   ii) Consider a market-based trading program to most economically achieve emissions goals;
   iii) Consider an expanded system to track compliance with emissions limits, inspection, and enforcement tools and stricter penalties for violators;
   iv) Use legal and regulatory approaches to implement air pollution control; and
   v) Evaluate the extent to which control measures have lead to achievement of air quality goals and determine what additional or modified activities are necessary.
6) Future capacity building goals:
   i) The Chinese side stated that they would greatly benefit from further more detailed training, particularly in the areas of the overall U.S. air quality management process and modeling capacity building in support of policy development, and use of legal, regulatory, and market-based approaches.

Project Planning

In meetings regarding overall project status and goals for the project and for the Assessment Report, representatives of the U.S. and Chinese sides expressed their satisfaction with meeting results and desire for continued technical and capacity building exchanges. U.S. EPA and

SEPA also continued discussions regarding planning for the proposed Chinese delegation visit to the U.S.

March 2002 Chinese Delegation Visit to U.S.

Based on discussions during the May 2001 meetings in Shanghai, SEPA, U.S. EPA, and SEPB continued work to arrange and finance a Chinese delegation visit to the U.S. This trip took place March 18-24, 2001 and included meetings and technical exchange hosted by U.S. EPA at Research Triangle Park, NC and Washington, DC.

In addition to project-related discussions, meeting participants toured an integrated ambient air monitoring station run by the North Carolina Department of Environment and Natural Resources, the new U.S. EPA RTP campus and had special discussions with senior U.S. EPA officials John Seitz, David Mobley and John Bachmann. While in Washington, DC members of the Chinese delegation presented the results of the Integrated Energy Options and Health Benefits Study for Shanghai at a seminar hosted by the Woodrow Wilson International Centers for Scholars and U.S. EPA Office of Atmospheric Programs. The seminar was well received and attended.

Assessment Report

Meeting participants also reviewed and discussed the first draft by U.S. EPA of the Assessment Report, which representatives of the Chinese side stated was a good first draft and included the subject matter identified in the May 2001 meetings. The Chinese side expressed interest in adding further information, detail and analysis regarding the U.S. air quality management process and how it compares to China, based on the information presented during the visit, and agreed to further develop the China-related sections of the report to complement the topics and detail of the U.S. sections. Over the course of several days of detailed meetings regarding the draft Assessment Report, participants discussed the additional information that should be added to the report and other changes that should be made in order to ensure that the Report achieved both sides' goals of increasing understanding of Air Quality Management in both countries, having a practical positive benefit on air quality in China, and forming the foundation for further U.S.-China cooperation. Meeting participants also agreed that the report should also be used to support development of project proposals for international funding organizations.

Technical Presentations and Information Exchange

In addition to the above discussions, U.S. and Chinese meeting participants made a series of presentations regarding a wide range of technical, policy and programmatic issues, including:

- China 9th National Plan, Environmental Planning for Beijing Olympics;
- Shanghai Air Quality Management Plan and Its Relation to National Plan/Summary of Shanghai Air Quality Management and Planning Process: A Technical and Institutional Perspective;
- Shanghai Energy Option and Health Benefits Project;
- Proposed China National/Regional AQ Modeling Assessment Project;
- U.S. AQM: Past, Present, and New Approaches;
- EPA Public Outreach/ Air Quality Index;

- EPA Resources and Accountability;
- EPA Air Toxics Program;
- U.S. Regional Ozone Emissions Transport and Transboundary Air Pollution Regulations;
- U.S. Air Pollution Health Benefits Analysis);
- EPA Air Quality Education and Outreach;
- EPA Air Pollution Training and APTI Virtual Classroom;
- New U.S. EPA/RTP Facility;
- Air Toxics and Proposed Dioxin Conference;
- EPA Integrated Environmental Strategies Program;
- EPA Economic Instruments for AQ Regulations/Acid Rain Program;
- EPA Transportation AQ, Planning, and Management;
- U.S.-China Cooperation on Economic Modeling and Ancillary Benefits;
- EPA "3P" Approach to Multi-Pollutant Regulation;
- EPA Compliance and Enforcement; and
- EPA Clean Air Excellence Award Program.

Next Steps for Near-term Project Cooperation

Finally, meeting participants discussed possible next steps for project cooperation focused on high priority activites that SEPA and Shanghai EPB are working on and would like to accomplish over the next 12 months and for which staff and budgetary resources were already available. The project's goal would be to complement and support these activities.

SEPA identified its most important near-term tasks as:

1) Allocation of emissions under the 10th Fifth Year Plan to provincial EPBs, in particular emissions caps (especially for SO2). SEPA has already completed the regional allocation, but emissions must be further allocated to provinces and sources;
2) SEPA has designated a list of 60 key cities where AQ exceeds national standards. These cities will have to develop compliance plans to meet level 2 standards and would in particular like to apply the U.S. experience in calculating control strategy cost effectiveness to optimize selection of control strategies. SEPA would like to establish a methodology so that all 60 cities would use the same calculation method. This effort could build on U.S. EPA's Criteria Air Pollutant Modeling System (CAPMS) expertise and should take less than one year to accomplish; and
3) Development of motor vehicle emissions controls (to be issued by SEPA).

Shanghai EPB identified the following environmental problems to be addressed in the short term:

1) Particulate matter: (a) source apportionment to determine what the sources are so that policies can be be develop (including PM transported from other regions), (b) PM emission

inventory development, (c) expansion of the ambient monitoring network, and (d) selection of control measures, including cost-benefit analysis;

2) Ozone issues (particularly as related to visibility); and
3) SO2 allowances (Shanghai EPB is working on this through another U.S. EPA project, so don't need additional help on this).

U.S. and China monitoring experts identified the following potential priority activities:

1) Monitoring techniques for ozone and sampling and analysis methods for VOCs as requested by the Shanghai EPB;
2) Transfer to SEPA and Shanghai EPB of the Standard Operating Procedures (SOPs) for continuous criteria pollutant monitoring methods and network siting protocols which U.S. EPA uses to implement the National Ambient Monitoring Sites;
3) Transfer to CRAES (in support of SEPA) and Shanghai EPB of U.S. EPA technologies regarding PM2.5 chemical speciation;
4) Transfer of U.S. EPA's experience with air toxics monitoring methods and analysis protocols along with associated QA/QC procedures to Shanghai EPB; and
5) In the longer term, development of a project with CRAES and SEPA EPB's (outside funding support would probably be needed) to develop and support state of the art PM2.5 sampling instrumentation capabilities at CRAES and three major cities in China (including Shanghai). The objectives include, in particular, training in collection and analysis of samples and analysis of the resulting data. CRAES would provide overall project coordination with Shanghai EPB and others.

U.S. and China modeling and inventory experts identified the following potential priority activities:

1) Short-term effort in "National/Regional Modeling Assessment Demonstration Project”. This short term project would take approximately 6~8 months and a budget of $40,000, or RMB 330,000, (estimate) and focus on PM2.5, ozone, acid rain, and visibility. Major activities would include: (a) Review existing emissions inventory (prepared in conjunction with David Street) and convert it to data format needed for the China national Models-3/CMAQ simulation, (b) Prepare meteorological data (running MM5) as inputs to the Models-3/CMAQ system, and (c) Build demonstration capability and identify areas for further work to set the basis for the longer term project; and
2) Medium-long term urban air quality strategy: Target the urban areas around Shanghai, Beijing/Tianjin and possibly extend to Guangzhou and Chongching. The effort will include: (a) technical training, (b) capacity builing, (c) emission inventory improvements, (d) modeling assessment, and (e) control strategy development and cost/benefit analysis. This project will take 1-3 years to implement.

Several other avenues for cooperation were discussed, including:

1) Formal international workshop to publicize and promote the Assessment Report;
2) Establishment of a China Air Quality Management Center of Excellence, with involvement of U.S. experts to serve as a base for training programs and information exchange regarding air quality management;

3) Particulate matter technical workshop in China;

4) Possible Dioxin/Furan workshop in Shanghai; and

5) Air Toxics Program Development Training in Shanghai. *The workshop on air toxics was held in Shanghai in November 2003. The U.S. experts presented the U.S. air toxics program and explained how the program was developed and implemented. The workshop was hosted by the Shanghai EPB.*

Current Activities

Early in 2003, the U.S. EPA and SEPA recognized opportunities for building on and integrating the successful work undertaken under the cooperative "Statements of Intent" initiated in the late 1990's, as well as other bilateral activities related to clean air and energy initiated in the previous decade. For the most part, these projects were developed and implemented independently, with no systematic effort to coordinate activities (in the U.S. or China) among project managers and groups leading these efforts. It was apparent that substantial coordination and integration of these efforts would likely increase their effectiveness. This could significantly advance China's capabilities to manage air quality and utilize clean energy technologies and help achieve major reductions in air pollution and greenhouse gases. U.S. EPA and SEPA began discussing a "strategy" that could help guide our future cooperation, facilitate the integration of key projects, leverage expertise and resources from other partners, and target key areas such as indoor air and transportation that had not yet been addressed. It could also help to improve coordination with other air program efforts that China had been successful in pursuing with international agencies, foreign governments and, increasingly, the private sector. The result of these discussions was the *Strategy for Clean Air and Energy Cooperation between the U.S. EPA and SEPA*. This Strategy was the centerpiece of the Air Annex under the *Memorandum of Understanding on Scientific and Technical Cooperation in the Field of Environment* signed by U.S. EPA and SEPA on December 8, 2003 (http://www.epa.gov/oia/regions/Asia/index.html).

The primary goal of the Strategy is "to enhance the effectiveness of collaborative efforts to reduce the emissions intensity (air pollution and greenhouse gases) of China's rapidly growing economy." The Strategy establishes a framework for cooperation with two main approaches: 1) stronger coordination and integration of clean air and energy management by focusing multiple programs and projects in Beijing and the surrounding region, and 2) prioritization of current and emerging sectors that affect air, environment and public health, such as transportation and the power sector, to enable sound decisions about how to best manage pollution from these sectors as they grow. The Strategy seeks to strengthen linkages and coordination among many of the existing SEPA-EPA partnerships, as well as partnerships with similar efforts such as air quality objectives related to the Beijing 2008 Olympics. The Strategy also enhances the scientific and technical basis for air quality management in China by building capacity to apply advanced tools to evaluate the potential of local, regional and national clean energy and transportation measures to reduce air pollution and its impacts on the environment and public health. The Strategy also seeks to leverage cooperation and support from other organizations and nations with expertise, resources and interest in addressing air quality issues in China.

Core Team Members

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APPENDIX B
Sources of Financial Assistance

Introduction

The U.S./China Air Quality Management Assessment Report highlights a number of opportunities and measures for enhancing urban air quality management in China. Many of these measures would require significant funding, sometimes at levels beyond the resources available to local or municipal governments. This appendix identifies four possible sources of international financial assistance for air quality management initiatives in China.

Multilateral Development Banks

- ***The World Bank*** is very active in China, with a stated overall objective of supporting economic and social development efforts. Within this objective, one of the World Bank's strategic focus areas in China is "facilitating an environmentally sustainable development process through investment lending that demonstrates new management techniques and technologies". The World Bank has supported and continues to support many initiatives in China with environmental goals, including in particular urban pollution control. World Bank offers support in the forms of loans, grants, and analytical and advisory assistance. Further information is available on the web at: www.worldbank.org, or via the World Bank office in Beijing, at Level 16, China World Tower 2, China World Trade Center No.1, Jian Guo Men Wai Avenue Beijing 100004, Tel: 86-010-5861 7600
- ***The Asian Development Bank (ADB)*** has also been very active in China since China became a member of this bank in 1986. Poverty reduction is at the core of ADB's development support program, and environmental protection is one of ADB's identified strategic objectives in China. ADB provides support in the forms of loans and technical assistance projects. Further information is available on the web at http://www.adb.org, or via the ADB resident mission in Beijing, at 7th floor, Block D, Beijing China Merchants International Finance Center, 156 Fuxingmennei Ave., Beijing, 10003, Tel 86-010-6642 6601 to 6605

Bilateral Support

- ***The United States Trade and Development Agency (USTDA)*** has an active China program. "USTDA's mission is to advance economic development and U.S. commercial interests in developing and middle-income countries. To this end, the agency funds various forms of technical assistance, feasibility studies, training, orientation visits and business workshops that support the development of a modern infrastructure and a fair and open trading environment. In carrying out its mission, USTDA gives emphasis to economic sectors that may benefit from U.S. exports of goods and services" (http://www.tda.gov). USTDA supports environmental programs, and in particular has funded a feasibility study for enhancing Shanghai's air quality monitoring systems, a program very much in line with the findings of the U.S./China Air Quality Management Assessment Project. Further information can be found on the web at http://www.tda.gov.

Export Import Credit Agencies

- ***The Export-Import Bank (Ex-Im Bank) of the United States*** "is the official export credit agency of the United States and supports the purchase of U.S. goods and services by creditworthy Chinese buyers that have difficulty obtaining credit through traditional financing sources. Ex-Im Bank support is available in China for short-, medium-, and long-term transactions in both the public and private sectors. Ex-Im Bank financing can enhance Chinese buyers' access to U.S. goods and services. Ex-Im Bank provides enhanced support for imports of environmentally beneficial goods" (http://www.exim.gov/products/chinaexp-en.pdf). Recently Ex-Im Bank provided a loan guarantee supporting the purchase of 5.2 million dollars worth of air quality monitoring equipment by SEPA from U.S. suppliers. Further information can be found on the web at http://www.exim.gov.